Treatment of Peri-implant Mucositis: An AAP/AO Systematic Review and Meta-analysis

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Purpose: To assess whether adjunctive treatment modalities offer therapeutic advantages when used in combination with peri-implant debridement—defined as supra- and/or submarginal debridement using manual, sonic, and/or ultrasonic instrumentation—for the treatment of peri-implant mucositis. ***Materials and Methods:*** Relevant articles published in English between January 1980 and October 2023 were searched. Clinical trials involving ≥ 10 patients diagnosed with peri-implant mucositis and treated with debridement alone versus debridement plus an adjunctive treatment were included. Data were extracted and meta-analyses were performed to investigate the effect of different therapeutic approaches on several outcomes of interest (ie, pocket depth [PD] and bleeding on probing [BoP] reduction as well as complete disease resolution). ***Results:*** A total of 25 articles were selected, of which 19 were included in the meta-analyses. Peri-implant debridement generally resulted in PD and BoP reduction. For studies including nonsmokers or patients with unclear smoking status, outcomes of individual studies revealed that the use of certain probiotics, such as *Lactobacillus reuteri* strains, may modestly reduce BoP in the short term. For studies exclusively involving smokers or users of vapes/electronic cigarettes, the clinical benefits of adjunctive therapy were negligible. Complete disease resolution was not consistently achieved regardless of the treatment modality. ***Conclusions:*** Peri-implant debridement as a monotherapy for the treatment of peri-implant mucositis generally results in clinical improvements in terms of PD and BoP reduction. The use of adjunctive treatment modalities does not appear to provide a clinically significant additional therapeutic benefit compared to debridement alone, independent of the patient's smoking status. Complete peri-implant mucositis resolution is an elusive outcome. *Int J Oral Maxillofac Implants 2025;40(suppl):s49–s72. doi: 10.11607/jomi.2025suppl2*

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Over the past several decades, implant-supported prostheses have become the prime therapeutic option to replace missing teeth in many clinical scenarios.[1] According to data from seven National Health and Nutrition Examination Surveys conducted between 1999 and 2016, there has been a substantial increase in the use of dental implant therapy in the United States, surging from 0.7% in 2000 to 5.7% in 2016; this representing an average annual increase of 14%.[2] Despite the advantages and growing popularity of dental implants, the prevalence of peri-implant diseases and conditions—many of which are associated with patient discomfort, suboptimal esthetics, and even loss of function—has also increased in recent years.[3,4]

The etiology of peri-implant diseases, including peri-implant mucositis and peri-implantitis, is multifactorial.[5] A case of peri-implant mucositis is characterized by bleeding on probing (BoP) with or without mucosal erythema, localized swelling and/or suppuration, and no progressive alveolar bone loss beyond the expected physiologic remodeling after delivery of the final implant-supported prosthesis. Peri-implant mucositis precedes peri-implantitis, which is a plaque-associated pathologic condition that affects peri-implant tissues characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone.[5]

It has been reported that the prevalence of peri-implant mucositis is 48% at the implant level over a longitudinal follow-up of up to 14 years.[3] A systematic review conducted by Lang et al[6] revealed that gingivitis and peri-implant mucositis share fundamental similarities in terms of their pathogenesis and diagnosis. Both conditions represent a host response to the bacterial challenge posed by biofilm accumulation. However,

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experimental studies in humans have also revealed that peri-implant soft tissues typically exhibit a stronger inflammatory response to microbial biofilm accumulation compared to gingival tissues.[7] Some proposed that the precipitating or predisposing factors for peri-implant mucositis are poor oral hygiene, lack of compliance with supportive implant therapy, prosthetic designs that impair access for adequate biofilm removal, insufficient keratinized mucosa width (< 2 mm), and excess residual cement.[4]

Because the host response to microbial biofilm accumulation that results from a local inflammatory process is generally considered the primary cause of this condition, patient education and clear provisions of oral hygiene instructions for effective plaque control through self-performed hygiene measures is a foundational component of preventive therapy. On the other hand, upon a diagnosis of peri-implant mucositis, professional intervention—based on supra- and submucosal debridement—represents the primary line of treatment and has been shown to effectively obtain a reduction in clinical signs of inflammation.[8] The effect of adjunctive treatment modalities, such as pharmacotherapeutics (eg, systemic or locally delivered antimicrobials), air-polishing devices, and laser therapies, has been the subject of controversy due to the heterogeneity and inconsistency of the outcomes observed in numerous clinical studies.[4,8]

Therefore, the objective of this systematic review was to assess whether adjunctive treatment modalities offer therapeutic advantages when employed in conjunction with peri-implant debridement—defined as supra- and/or submarginal mechanical debridement using manual, sonic, and/or ultrasonic instrumentation—for the treatment of peri-implant mucositis compared to debridement alone. The focused question addressed in this review was "Do adjunctive treatment modalities provide a therapeutic benefit when combined with mechanical debridement for the treatment of peri-implant mucositis?"

MATERIALS AND METHODS

This systematic review was designed and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[9] and the Cochrane Handbook of Systematic Reviews of Interventions.[10] The study protocol was registered in the PROSPERO database (CDR42023484502). Specific details of the PICO (population, interventions, comparisons, and outcomes)[11] framework that was used to devise the focused question are described in the following section.

Eligibility Criteria and Outcome Measures

Only randomized clinical trials (RCTs) were considered eligible for inclusion if they met the following criteria: *(1)* Treatment of patients who were at least 18 years old and presented with peri-implant mucositis; *(2)* a minimum of 10 participants per treatment arm at the final follow-up examination; *(3)* assessment of implant surface debridement (eg, supra- and/or submarginal debridement using hand scaling and/or sonic/ultrasonic instrumentation) without surgical flap access versus adjunctive treatment modalities such as—but not limited to—air-polishing devices, pharmacotherapeutics (systemic/local antibiotics, antiseptics, etc), antimicrobial photodynamic therapy (aPDT), and laser therapy; *(4)* a follow-up period ≥ 3 months; and *(5)* reporting at least one of the following outcomes of interest (mean and/or percentage): changes in pocket depth (PD), clinical attachment level (CAL) gain, BoP reduction, marginal mucosa position changes, histologic and/or biomarker outcomes, and the percentage of complete resolution cases of peri-implant mucositis, which was defined by the absence of BoP at the implant site.

The following article types were excluded from the present analysis: nonrandomized controlled trials, case reports/series, observational studies, editorials, letters or comments, articles with non-English citations, animal/in vitro studies, and review articles.

Information Sources and Search Strategy

To streamline the identification of potentially eligible studies published between January 1980 and October 2023, two independent examiners (G.H.L. and Y.R.) conducted a literature search using specific search strategies in the following three databases: *(1)* Ovid MEDLINE, *(2)* EMBASE, and *(3)* Dentistry and Oral Sciences Source. For more details related to search terms, see Appendix Fig 1 at the end of this article. Additionally, a hand search of peer-reviewed journals was conducted and included the following journals: Journal of Periodontology, Journal of Clinical Periodontology, Clinical Implant Dentistry and Related Research, International Journal of Oral and Maxillofacial Implants, Clinical Oral Implants Research, Journal of Dental Research, Journal of Prosthetic Dentistry, International Journal of Prosthodontics, Journal of Oral Implantology, and International Journal of Periodontics and Restorative Dentistry.

Data Extraction

Data on the outcomes of interest were extracted from the selected articles by two independent reviewers (G.H.L. and Y.R.) for subsequent qualitative and quantitative analyses. The collected data included author names, year of publication, study design, sample size, demographic information of the participants (ie, age,

sex, and smoking status), type of adjunctive treatment, and follow-up period. Outcomes that were considered for the quantitative analyses included PD reduction, CAL gain, BoP reduction, marginal mucosa position gain, histologic and/or biomarker outcomes, and the percentage of complete disease resolution. Corresponding authors were contacted if additional data and/or further clarification regarding study methods were needed.

Risk of Bias Assessment

The revised Cochrane Risk of Bias 2 (RoB 2) tool was employed to evaluate the following methodologic aspects of included RCTs: *(1)* Bias arising from the randomization process, *(2)* bias due to deviation from intended intervention, *(3)* bias due to missing outcome data, *(4)* bias in the measurement of the outcome, and *(5)* bias in selection of the reported result. The degree of bias was categorized as low, high, or some concerns.[12]

Data Synthesis

Data were pooled into evidence tables and displayed according to the type of adjunctive therapy. A descriptive summary was performed to display individual studies' outcomes and variations across different therapies. Forest plots were produced to graphically represent outcome differences between the two groups using the number of implants as the unit of analysis. Due to the various adjunctive treatments used in combination with debridement, subgroup analyses were also conducted to investigate the benefit of individual adjunctive treatment compared to debridement alone. The subgroup meta-analysis estimate assessments and interpretation were only performed if at least two RCTs within the same adjunctive treatment modality reported on the same outcome of interest. For these comparisons, the pooled outcomes were expressed as weighted mean differences (WMD) with their associated 95% confidence intervals (CIs). Analyses were performed using the RevMan (version 5.0) computer software (Cochrane). A *P* value of .05 was used as the level of significance. Heterogeneity was assessed with the I^2 test, which ranges between 0% and 100%, with lower values indicating less heterogeneity. Random-effects meta-analyses of the data extracted from the selected studies were conducted if the I^2 test showed a value > 50%, whereas fixed-effects meta-analyses were conducted if the I^2 test presented a result < 50%.

RESULTS

Study Selection

The screening process is displayed in Fig 1. Electronic and hand searches yielded 151 articles, of which 41 articles were selected for full-text evaluation after screening their titles and abstracts. Of these, 16 articles were excluded (see Appendix Table 1 at the end of this article).[13–28] Therefore, 25 articles (for a total of 24 clinical trials) were included in this systematic review.[29–53] The kappa (k) value for the interreviewer agreement was 0.85 for titles and abstracts and 0.93 for the full text, indicating an "almost perfect" agreement between the two reviewers.[54]

Included Studies

The main aspects of the included studies are summarized in Table 1. The findings of one trial were reported in two separate papers (ie, clinical[44] and microbiologic[45] outcomes) but are displayed under one study name.[44,45]

All the selected RCTs included a control group consisting of peri-implant debridement alone. Regarding the use of adjunctive therapy in the experimental group, the following materials were used in the included articles: two studies involved the use of air-polishing devices for implant surface decontamination,[43,49] a diode laser was employed in two studies,[29,44] one study had one interventional arm using an air-polishing device and another arm using an Er:YAG laser,[35] aPDT was applied in four studies, [30,31,42,51] systemic azithromycin was administered in one study,[39] one study had one interventional arm that involved the use of aPDT and another arm in which oral azithromycin was administered,[36] an oral probiotic (*Lactobacillus reuteri*) was prescribed to participants in three studies,[32,37,52] in one study an oral probiotic and a topical probiotic gel (*Bifidobacterium lactis*, *Lactobacillus rhamnosus*, and *Lactobacillus paracasei*) were used,[5] five studies involved the topical use of an antimicrobial rinse,[33,34,45–47] a topical antimicrobial gel was used in three studies,[38,40,41] and in two studies both an antimicrobial gel and chlorhexidine rinse were topically applied in the diseased sites.[48,53]

Of the 24 included RCTs, two of them exclusively enrolled cigarette smokers,[36,42] one study only included individuals using vapes/electronic cigarettes,[30] and one study recruited smokeless tobacco users only.[31] In addition, one study distributed nonsmokers and smokers into two separate arms,[32] and eight studies recruited nonsmokers exclusively.[34,37,43,45,48,50–52] The smoking status of participants was not reported in three articles.[33,39,44] All other trials included both smokers and nonsmokers in each of the study arms. The follow-up period ranged from 3 to 12 months.

RoB Assessment

The results of the RoB assessment for the included RCTs are displayed in Appendix Table 2 at the end of this article. Of the 24 included studies (reported in 25 articles), 12 of these exhibited a low RoB,[29,30,32–35,37–39,45,50,52] some concerns related to the RoB were

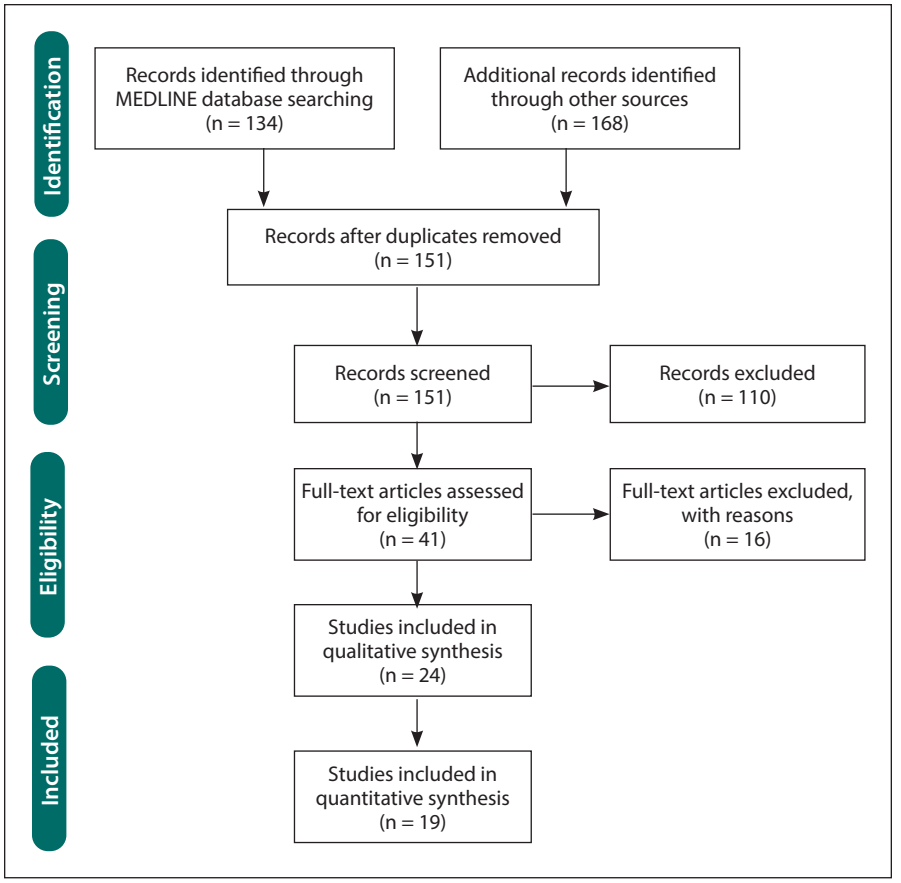

Fig 1 Flowchart illustrating the article selection process.

observed in 7 trials ,[36,40–42,46,47,49,51] and 5 trials had a high RoB.[31,43,44,48,53]

Effects of Interventions: Individual Study Outcomes and Pooled Estimates

Among all the 24 included studies, 4 of them[33,42,48,51] reported a statistically significant difference in PD reduction, 1 study[48] reported a significant difference in CAL gain, 2 studies[44,50] reported a significant difference in BoP reduction, and 7 studies[30,33,34,38,42,44,51] reported a significant difference in plaque reduction, favoring the adjunctive treatment group.

Meta-analyses were conducted using data on PD reduction, BoP reduction, and the percentage of complete disease resolution at the implant level extracted from 19 of the selected studies. Four of these studies[30,32,36,42] only included smokers or users of vapes/electronic cigarettes.[28,30,34,40] Therefore, due to the possible impact of vaping/smoking on the treatment outcomes, data from these studies were pooled separately from the other 15 studies.[29,33,35,37,39,41,43,45,47–53]

In studies in which antimicrobial rinses were used as the adjunctive treatment,[33,45,47] only the data from the study arm involving the use of chlorhexidine were analyzed to avoid pooling the data from treatments that combined various rinses together.

Studies Including Nonsmokers or Patients with Unclear Smoking Status

Data from 15 studies including nonsmokers or patients with unclear smoking status were pooled in the forest plots.[29,33,35,37,39,41,43,45,47–53] To investigate the potential benefits of each adjunctive treatment, subgroup analyses were performed when at least two RCTs were available for analysis in a single subgroup. For PD reduction, no statistical significance was found for any of the subgroup comparisons (Fig 2a).

Regarding BoP reduction, data from 11 studies were analyzed.[29,32,35,37,39,45,47,49,50,52,53] One study[35] had two test arms included in different subgroup analyses; therefore, the control arm was pooled twice. Of the subgroup analyses that including at least two trials, only the probiotic subgroup (WMD = 10.39%; 95% CI = 7.64% to 13.14%; $P < .0001$), which included four studies,[32,37,50,52] was found to promote additional improvements to those achieved by mechanical debridement alone (Fig 2b). Most of the subgroups exhibited low heterogeneity, except for the probiotics and chlorhexidine rinse subgroups.

In terms of the percentage of complete disease resolution at the implant level, five studies were included in the forest plot.[29,35,41,47,50] The only subgroup comparison available for analysis did not find a statistically

significant difference between the test and control groups (Fig 2c).

Studies Exclusively Involving Smokers or Individuals Using Vapes/Electronic Cigarettes

Data from four studies including only smokers, vapers, or electronic cigarette users were pooled.[32,37,50,52] One study[36] had two test arms included in different subgroup analyses; therefore, the control arm was pooled twice. Again, subgroup analyses were conducted when at least two RCTs were available for analysis in a single subgroup. Regarding PD reduction and BoP reduction, only the aPDT subgroup included more than one study for analysis. The outcomes from patients who received the control treatment or aPDT did not render a statistically significant difference for PD reduction (Fig 3a) and BoP reduction (Fig 3b). However, these comparisons showed a high degree of heterogeneity among the pooled studies. Note that none of the studies exclusively recruiting smokers reported data on the percentage of complete disease resolution.

DISCUSSION

Summary of Main Findings

The findings of this comprehensive systematic review demonstrated that the use of adjunctive treatment modalities (ie, air-polishing, aPDT, lasers, antibiotics, local antimicrobials, and probiotics) employed in conjunction with peri-implant debridement for the treatment of peri-implant mucositis does not significantly improve the clinical outcomes achieved with debridement alone. Outcomes from individual studies displayed contrasting results, with most included trials not supporting the use of adjunctive therapies. Most pooled estimates demonstrated that peri-implant debridement plus adjunctive treatment did not render an additional benefit in terms of PD and BoP reduction, independent of the patient's smoking status. Subgroup analyses suggested potential benefits in terms of BoP reduction only for the use of probiotics in nonsmokers in the short term.

Limitations and Potential Biases in the Review Process

Recent reports indicate that the presence of BoP should not be used solely to diagnose peri-implant disease.[55–57] A peri-implant diagnosis should be established based on the presence or absence of BoP and other parameters, such as visual signs of inflammation, changes in PD, and progressive bone loss. The Implant Dentistry Core Outcome Set and Measurement (ID-COSM) consensus indicated that the diagnosis of peri-implant mucositis should be defined as the presence of BoP in more than one spot around the implant or the presence of a line of bleeding/profuse bleeding at any location and/or suppuration on gentle probing with an absence of bone loss beyond crestal bone level changes that resulted from initial bone remodeling.[57] Nevertheless, none of the selected studies in this review incorporated this recently proposed case definition.

Another factor that may influence treatment outcomes is the provision of oral hygiene instructions to patients. While the majority of the included studies offered oral hygiene guidance to participants, six studies[31,33,37,41,42,51] did not specify whether such instructions were provided. Notably, these studies reported a greater reduction in their reported plaque index scores for patients receiving adjunctive treatment compared to those who only received peri-implant debridement. However, it is well established that an effective microbial biofilm control program is crucial for restoring peri-implant health.[48,55] Therefore, the findings from studies lacking a specified oral hygiene program should be interpreted with caution when assessing the effectiveness of various adjunctive treatments and their potential to restore peri-implant health.

While this systematic review explored the impact of adjunctive treatment in resolving peri-implant mucositis compared to debridement alone, it is essential to highlight that we did not specifically assess the effect of professionally administered versus patient self-performed plaque control protocols in managing peri-implant mucositis,[58] nor did we compare supragingival debridement to subgingival instrumentation. Previous studies have suggested that mechanical plaque control alone should be considered the standard of care in the management of peri-implant mucositis, and clinical improvements could be achieved by incorporating professional submarginal instrumentation with adjunctive measures following oral hygiene instructions (eg, use of an antimicrobial mouth rinse).[58,59]

In addition, despite the additional improvements promoted by aPDT (PD reduction in nonsmokers), systemic antibiotics (PD reduction in smokers, BoP reduction in nonsmokers and smokers), and probiotics (BoP reduction in smokers) displayed in some of the forest plots, formal subgroup analyses could not be performed via pairwise meta-analysis because only one study was available in each subgroup. Moreover, it is important to emphasize the high degree of heterogeneity found for almost all sets of forest plots (see Figs 2 and 3). This outcome seems mostly linked to the authors' choice to pool data from different treatment approaches into subgroups to generate one big dataset. Therefore, differences related to the peri-implant mucositis definition and methods/protocols used to treat patients may have influenced the overall extent of changes promoted by different treatment options regarding the potential

Table 1 Features of the Included Articles that Reported Outcomes After a Surgical Approach

Surgical approach	Authors (year)	Study design and smoking status	Adjunctive treatment in test group(s) in addition to MD	Control group	OHI program	No. of patients (N)	No. of implants (N)	Follow-up (months)
Air-polishing	Clementini et al[35] (2023)	RCT including light smokers	Erythritol powder air-polishing for 5 seconds at an angle of 60 to 90 degrees	MD using titanium curettes	Yes	T: 25 14 m/11 f C: 25 12 m/13 f	T: 62 C: 58	6
	Ji et al[43] (2014)	RCT in nonsmokers	Glycine powder air-polishing	MD using ultrasonic instrument	Yes	T: 12 6 m/6 f C: 12 4 m/8 f	T: 17 C: 16	3
	Riben-Grundstrom et al[49] (2015)	RCT including 5 smokers	Glycine powder air-polishing	MD using ultrasonic instrument at baseline and at 3 and 6 months	Yes	T: 19 10 m/9 f C: 18 9 m/9 f	T: 19 C: 18	12
Lasers	Aimetti et al[29] (2019)	RCT including light smokers	Diode laser (980 nm) at 2.5 watts in pulsed mode (mean 0.7 watts, 10 kHz) using a 300-µm optical fiber	MD using ultrasonic device and titanium-coated curettes	Yes	T: 110 32 m/78 f C: 110 39 m/71 f	T: 110 C: 110	3
	Clementini et al[35] (2023)	RCT including light smokers	Er:YAG laser light in a noncontact mode at an energy level of 100 mJ/pulse and frequency of 10 Hz	MD using titanium curettes	Yes	T: 25 13 m/12 f C: 25 12 m/13 f	T: 59 C: 58	6
	Lazar et al[44] (2023)	Split-mouth RCT; did not report smoking status	Diode laser (980 nm) with a power of 12 watts in pulsed system using a 300-µm optical fiber	Scaling around the implant surface using titanium curettes	Yes	T: 21 9 m/12 f C: 21 10 m/11 f	T: 21 C: 21	6
aPDT	Al-Sowygh[31] (2017)	RCT in smokeless-tobacco product users	aPDT	MD using plastic curettes	NA	T: 24 24 m C: 24 24 m	T: 24 C: 24	3

Treatment outcomes (differences)								
PD reduction (mm ± SD)	CAL gain (mm ± SD)	BoP reduction (%)	PI/PS reduction (± SD)	BI/BS reduction (± SD)	MMP gain (mm ± SD)	Complete resolution (%)	Microbiologic outcomes	Conclusions
T: 0.79 (1.42) C: 0.92 (2.65)	NA	T: 47.85 (68.15) C: 47.99 (67.89)	T: 47.85 (39.57) C: 39.65 (37.24) PS	NA	T: –0.05 (2.53) C: –0.01 (2.4)	T: 19/62 30.65% C: 17/58 29.31% implant level	NA	The adjunctive use of air-polishing did not provide significant benefit in terms of BoP and PD reductions and complete disease resolution.
T: 0.93 (1.11) C: 0.91 (1.18)	NA	NA	T: 1 (1.23) C: 0.2 (0.89) PI	T: 0.6 (1.36) C: 0.8 (1.53) BI	NA	T: 29.1% C: 42.1% treated sites	NA	Adjunctive air-polishing treatment seemed to have a limited beneficial effect as compared to MD alone.
T: 17% reduction C: 14% reduction in sites with ≥ 4 mm PD	NA	T: 31.8 (36.75) C: 35.1 (44.71)	T: 19.9 (35.7) C: 16.7 (40.44) PS	NA	NA	T: 92% C: 83% treated sites	NA	Nonsurgical treatment with an air-polishing device or ultrasonic device were equally effective in treating peri-implant mucositis.
T: 0.6 (0.8) C: 0.4 (0.7)	NA	T: 25.1 (29.2) C: 19.4 (26.7)	T: 23.2 (17.8) C: 17.9 (27.5) PS	T: 0.7 (5.3) C: 0.8 (6.1) BS	NA	T: 198/319 62.07% C: 166/305 54.43% treated sites T: 38/110 34.55% C: 34/110 30.91% implant level	NA	Adjunctive use of the diode laser did not yield any statistically significant clinical benefit as compared to nonsurgical MD alone.
T: 0.76 (1.39) C: 0.92 (2.65)	NA	T: 43.5 (40) C: 47.99 (67.89)	T: 49.15 (47.73) C: 39.65 (37.24) PS	T: 11.12 (18.82) C: 5.78 (11.68) BS	T: –0.15 (2.76) C: –0.01 (2.4)	T: 17/59 28.81% C: 17/58 29.31% implant level	NA	Adjunctive use of the Er:YAG laser did not provide significant benefit in terms of BoP and PD reductions and complete disease resolution.
T: 0.84 C: 0.15	NA	T: 1.77 C: 1.43 *	T: 35.76 C: 25 PS*	NA	NA	NA	NA	Laser therapy as an adjunct to peri-implant debridement led to more reduction in BoP and plaque score.
T group showed statistically significantly more reduction than C group.	NA	T group showed statistically significantly more reduction than C group.	T group showed statistically significantly more reduction than C group.	NA	NA	NA	NA	MD with adjunctive aPDT was more effective in treating peri-implant mucositis when compared to MD alone.

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Table 1 *(cont)* **Features of the Included Articles that Reported Outcomes After a Surgical Approach**

Surgical approach	Authors (year)	Study design and smoking status	Adjunctive treatment in test group(s) in addition to MD	Control group	OHI program	No. of patients (N)	No. of implants (N)	Follow-up (months)
aPDT	Al Rifaiy et al[30] (2018)	RCT in vaping patients	aPDT using 0.005% methylene blue with a diode laser (670 nm) at 150 mW for one minute	MD alone	Yes	T: 20 20 m C: 18 18 m	T: 38 C: 27	3
	Deeb et al[36] (2020)	RCT in smokers	aPDT using phenothiazine chloride with diode laser (660 nm) and 100-mW power density for 10 seconds at each site	MD with titanium curettes and polishing using rubber cups and paste	Yes	T: 15 15 m C: 15 15 m	T: 15 C: 15	3
	Javed et al[42] (2017)	RCT in smokers	aPDT with phenothiazine chloride and irradiated with a diode laser (660 nm) with a power density of 100 mW	MD using plastic curettes	NA	T: 28 28 m C: 26 26 m	T: 28 C: 26	3
	Shetty et al[51] (2022)	RCT in nonsmokers	aPDT with 0.005% methylene blue with a diode laser (660 nm) at 150 mW for 60 seconds using a flexible 300-µm fiber-optic tip	MD using sterile Gracey curettes	NA	T: 17 17 m C: 17 17 m	T: 17 C: 17	3
Antibiotics	Hallström et al[39] (2012)	RCT; did not report smoking status	Azithromycin 500 mg day 1 and 250 mg days 2 to 4	MD using titanium curettes and rubber cups	Yes	T: 21 C: 22	T: 21 C: 22	6
	Deeb et al[36] (2020)	RCT in smokers	Azithromycin 500 mg day 1 and 250 mg days 2 to 4	MD with titanium curettes and polishing using rubber cups and paste	Yes	T: 15 15 m C: 15 15 m	T: 15 C: 15	3

Treatment outcomes (differences)								
PD reduction (mm ± SD)	CAL gain (mm ± SD)	BoP reduction (%)	PI/PS reduction (± SD)	BI/BS reduction (± SD)	MMP gain (mm ± SD)	Complete resolution (%)	Microbiologic outcomes	Conclusions
T: 2.2 (0.14) C: 2.3 (0.2)	NA	T: 2.9 (0.51) C: 1.3 (0.2)	T: 37.9 (1.77) C: 19.3 (2.27) PS*	NA	NA	NA	NA	Antimicrobial aPDT is more effective compared to MD alone in the treatment of peri-implant mucositis in individuals vaping e-cigarettes.
T: 0.9 (0.35) C: 0.4 (0.33)	NA	T: 4.3 (0.40) C: 1.8 (1.46)	T: 33.0 (0.70) C: 30.5 (0.65) PS	NA	NA	NA	All the groups showed a significant reduction of *Pseudomonas aeruginosa* and *Staphylococcus aureus*, but there were no intergroup differences at 3 months.	No statistically significant differences were observed at 3 months for all clinical parameters between the test and control groups.
T: 5.9 (0.08) C: 2.8 (0.10) *	NA	T: 1.4 (0.23) C: 1.7 (0.16)	T: 37.2 (1.99) C: 28.0 (1.54) PS*	NA	NA	NA	NA	In cigarette smokers, MD with adjunctive aPDT was more effective in the treatment of peri-implant mucositis compared to MD alone.
T: 4.2 (0.21) C: 1.9 (0.31) *	NA	NA	T: 2.3 (0.41) C: 0.8 (0.28) PI*	T: 3.1 (0.20) C: 0.78 (0.22) BI*	NA	NA	There was a statistically significant reduction in the CFU/mL of oral yeasts in the test group compared with the control group at 3 months.	At 3-month follow-up, a single session of aPDT as an adjunct to MD was effective in reducing peri-implant inflammation and yeasts in patients with peri-implant mucositis.
T: 0.9 (1.53) C: 0.5 (1.54)	NA	T: 55.3 (31.71) C: 32.5 (42.11)	T: 26.9 (38.73) C: 4.1 (42.21) PS	T: 18.1 (22.36) C: 5.8 (24.86) BS	NA	NA	The statistical analysis failed to demonstrate study group differences in the changes of bacterial counts between baseline, 3 months, and 6 months.	No short-term differences were found between study groups. The findings did not provide evidence for the use of systemic antibiotics in the treatment of peri-implant mucositis.
T: 0.7 (0.38) C: 0.4 (0.33)	NA	T: 5.6 (1.29) C: 1.8 (1.46)	T: 38.5 (0.70) C: 30.5 (0.65) PS	NA	NA	NA	All the groups showed a significant reduction of *P aeruginosa* and *S aureus*, but there were no intergroup differences at 3 months.	No statistically significant differences were observed at 3 months for all clinical parameters between the test and control groups.

Table 1 *(cont)* **Features of the Included Articles that Reported Outcomes After a Surgical Approach**

Surgical approach	Authors (year)	Study design and smoking status	Adjunctive treatment in test group(s) in addition to MD	Control group	OHI program	No. of patients (N)	No. of implants (N)	Follow-up (months)
Probiotics	Alqahtani et al[32] (2019)	RCT in smokers	Probiotics containing active units of two *L reuteri* strains were given; one lozenge every 12 hours, twice a day for 3 weeks	MD using a sterile ultrasonic scaler with water irrigation	Yes	T: 20 20 m C: 20 20 m	T: 20 C: 20	6
		RCT in nonsmokers				T: 20 20 m C: 20 20 m	T: 20 C: 20	6
	Galofré et al[37] (2018)	RCT in nonsmokers	Probiotics presented in lozenges containing a combination of two strains of *L reuteri*	Supra-gingival prophylaxis with placebo tablets	No	T: 11 8 m/3 f C: 11 7 m/4 f	T: 11 C: 11	3
	Santana et al[50] (2022)	RCT in completely edentulous patients; nonsmokers only	Topical application and oral capsules containing 109 CFUs of *Bifidobacterium lactis* HN019, *Lactobacillus rhamnosus* HN001, and *Lactobacillus paracasei* Lpc-37; 14 capsules per week	MD using teflon-coated scalers, rubber cup, and polishing paste	Yes	T: 18 7 m/11 f C: 18 10 m/8 f 10 m/8 f	T: 18 C: 18	6
	Signorino et al[52] (2021)	RCT in nonsmokers	Probiotics given in lozenges containing a combination of two strains of *L reuteri* (DSM-17938 and ATCC PTA 5289) at a dose of 2 × 108 CFU/tablet	MD including supramucosal plaque removal and submucosal instrumentation using ultrasonic and hand instruments	Yes	T: 40 C: 40 32 m/48 f	T: 40 C: 40	3
Antimicrobial rinse	Alqutub et al[33] (2023)	RCT; did not report smoking status	T1: 0.12% CHX rinse T2: 2% sodium chloride rinse T3: Herbal-based mouthwash	MD using an ultrasonic hand scaler and manual curettes	NA	T1: 15 9 m/6 f T2: 15 10 m/5 f T3: 15 9 m/6 f C: 15 8 m/7 f	T1: 15 T2: 15 T3: 15 C: 15	3
	Alzoman et al[34] (2020)	RCT in nonsmokers	T1: 0.12% CHX rinse twice daily T2: Herbal-based mouthwash twice daily	MD using plastic curettes	Yes	T1: 16 10 m/6 f T2: 16 10 m/6 f C: 16 9 m/7 f	T1: 16 T2: 16 C: 16	3

Treatment outcomes (differences)								
PD reduction (mm ± SD)	CAL gain (mm ± SD)	BoP reduction (%)	PI/PS reduction (± SD)	BI/BS reduction (± SD)	MMP gain (mm ± SD)	Complete resolution (%)	Microbiologic outcomes	Conclusions
T: 0.6 (0.02) C: 0.8 (0.03)	NA	T: 5.3 (0.20) C: 4.1 (0.21)	T: 4.0 (0.80) C: 4.2 (0.59) PS	NA	NA	NA	NA	MD with adjunctive probiotics was more effectual in the treatment of peri-implantitis than MD alone in nonsmokers.
T: 0.9 (0.02) C: 0.2 (0.03) *	NA	T: 26.3 (0.40) C: 17.3 (0.40) *	T: 21.0 (0.40) C: 18.1 (0.39) PS*	NA	NA	NA	NA	
T: 0.48 (0.5) C: 0.15 (0.36)	NA	T: 32 (24) C: 7.1 (24)	T: 16 (17) C: 9 (4)	NA	NA	NA	T: 0.12 (0.88) decrease in total bacterial load C: 0.36 (1.01) increase in total bacterial load	The use of a daily lozenge of *L reuteri* for 3 months together with MD improved the clinical parameters of implants with peri-implant mucositis, but the microbiologic effect was much more limited.
T: 0.50 (0.12) C: 0.33 (0.05)	NA	T: 44.44 (0.95) C: 32.31 (2.20) *	No significant difference was observed between the test and control groups.	Test group showed higher percentage of sites with BI score 0 and lower percentage of sites with BI score 1 than the control group.	NA	T: 13/18 72.2% C: 6/18 33.3% implant level	Test group had more BoP reduction than the control group; no significant differences in immunologic parameters were detected between groups.	The multispecies probiotic (administered locally and systemically) as an adjunct to repeated MD promoted additional clinical and immunologic benefits in treating peri-implant mucositis.
T: 0.03 (0.11) C: 0.05 (0.16)	NA	T: 7.12 (3.65) C: –0.99 (17.31)	T: 14.29 (30.08) C: -0.31 (30.26) PS	NA	NA	NA	NA	No statistically significant differences were observed at 3 months for all parameters between the test and control groups.
T1: 4.2 (0.02) T2: 4.1 (0.01) T3: 4.1 (0.02) C: 2.7 (0.03 *	NA	NA	T1: 2.9 (0.04) T2: 2.9 (0.13) T3: 3.1 (0.08) C: 1.8 (0.05) PI*	T1: 3.4 (0.05) T2: 3.1 (0.08) T3: 3.4 (0.05) C: 1.6 (0.03) BI*	NA	NA	NA	After nonsurgical MD, postoperative use of CHX, the herbal or sodium chloride rinse was effective in treating peri-implant mucositis.
Groups 1 and 2 showed statistically significantly more reduction than C group.	NA	Groups 1 and 2 showed statistically significantly more reduction than C group.	Groups 1 and 2 showed statistically significantly more reduction than C group.	NA	NA	NA	NA	Herbal- and CHX-based oral rinses were useful adjuncts to MD for treating peri-implant mucositis.

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Table 1 *(cont)* **Features of the Included Articles that Reported Outcomes After a Surgical Approach**

Surgical approach	Authors (year)	Study design and smoking status	Adjunctive treatment in test group(s) in addition to MD	Control group	OHI program	No. of patients (N)	No. of implants (N)	Follow-up (months)
Antimicrobial rinse	Menezes et al[45] (2016)	RCT in nonsmokers	0.12% CHX mouth rinse with a prescription of twice daily for 14 days	MD with plastic curettes	Yes	T: 22 C: 15 6 m/31 f	T: 61 C: 58	6
	Philip et al[47] (2020) & Philip et al[46] (2022)	RCT including light smokers	T1: oral rinses with 0.2% delmopinol hydrochloride T2: 0.2% CHX rinse	MD using an ultrasonic device with a high-tech plastic material–coated tip	Yes	T1: 31 16 m/15 f T2: 30 16 m/14 f C: 28 16 m/12 f	T1: 31 T2: 30 C: 28	3
Antimicrobial gel	Hallström et al[38] (2017)	RCT including smokers	A full brush (approximately 0.5 g) of dental gel containing 0.2% CHX for a period of 12 weeks	MD using titanium curettes and rubber cup once a day	Yes	T: 19 C: 19 20 m/18 f	T: 19 C: 19	3
	Heitz-Mayfield et al[40] (2011)	RCT including light smokers	A plastic bottle containing 100 mL of 0.5% CHX gel for 4 weeks	MD using titanium-coated Gracey curettes or carbon fiber curettes followed by prophylaxis with a rubber cup and polishing paste	Yes	T: 14 8 m/6 f C: 15 6 m/9 f	T: 14 C: 15	3
	Iorio-Siciliano et al[41] (2020)	RCT including light smokers	An amino acid–buffered sodium hypochlorite gel delivered for 30 seconds	MD using an ultrasonic scaler with a plastic tip	NA	T: 22 8 m/14 f C: 23 11 m/12 f	T: 33 C: 34	6
CHX rinse with antimicrobial gel	Porras et al[48] (2002)	RCT in nonsmokers	Local irrigation with CHX 0.12% using a plastic syringe and the topical application of CHX gel with a prescription of twice daily for 10 days	MD using rubber cups and polishing paste, plastic scalers for removing calculus, and oral hygiene instructions	Yes	T + C: 16 NA	T: 16 C: 12	3

Treatment outcomes (differences)								
PD reduction (mm ± SD)	CAL gain (mm ± SD)	BoP reduction (%)	PI/PS reduction (± SD)	BI/BS reduction (± SD)	MMP gain (mm ± SD)	Complete resolution (%)	Microbiologic outcomes	Conclusions
T: 0.51 (0.81) C: 0.35 (0.91)	NA	T: 35.35 (49.74) C: 22.95 (50.38)	T: 28.28 (39.91) C: 38.36 (41.65) PS	T: 26.64 (39.65) C: 18.53 (36.01) BS	T: 0.32 (2.47) C: −0.06 (2.26)	NA	NA	The use of CHX did not significantly improve the outcomes for treating peri-implant mucositis.
T1: 0.53 (0.28) T2: 0.68 (0.03) C: 0.77 (0.04)	NA	T1: 41.94 (0.88) T2: 35.0 (0.85) C: 39.29 (1.01)	T1: 0.18 (0.02) T2: 0.09 (0.02) C: 0.27 (0.02) PI	T1: 0.87 (0.02) T2: 0.75 (0.02) C: 0.89 (0.02) BI		T1: 27/31 87% T2: 18/30 60% C: 20/28 71% implant level	Adjunctive antimicrobial therapy did affect peri-implant biofilm composition in the short term, resulting in a less dysbiotic subgingival biofilm.	There were no differences in clinical effects found between any of the groups at 3 months.
T: 36% reduction in sites with ≥ 4 mm PPD C: 15% reduction in sites with ≥ 4 mm PPD	NA	T: 4% C: 4%	T: 7% C: 0% *	NA	NA	NA	NA	The use of self-applied CHX gel along with nonsurgical MD could improve clinical parameters around implants.
NA	NA	No intergroup difference	Significant reduction in both groups after 10 days; less plaque accumulation in the test group at the last follow-up	NA	NA	11/29 (37.9%)	There were no significant differences in mean total DNA counts between test and control groups.	Adjunctive CHX gel application did not enhance the results compared with MD alone.
T: 0.88 (1.04) C: 0.61 (0.75)	NA	No statistically significant difference between groups	No statistically significant difference between groups	NA	NA	T: 15/33 45.45% C: 11/34 32.35% implant level	NA	Changes in PD, BoP, and PI from baseline to 6 months were not statistically significantly different between groups.
T: 0.56 (1.11) C: 0.93 (0.99)	T: 0.33 (2.29) C: 1.07 (1.87)	No difference in BoP at different time points	No difference in plaque index at different time points	No difference in bleeding index at different time points	NA	NA	At 3 months, there was a marked improvement in all categories of microorganisms.	Adjunctive CHX did not show additional benefit compared to MD alone.

Table 1 *(cont)* **Features of the Included Articles that Reported Outcomes After a Surgical Approach**

Surgical approach	Authors (year)	Study design and smoking status	Adjunctive treatment in test group(s) in addition to MD	Control group	OHI program	No. of patients (N)	No. of implants (N)	Follow-up (months)
CHX rinse with antimicrobial gel	Thone-Muhling et al[53] (2010)	RCT including 5 smokers	1% CHX gel applied once subgingivally; the dorsum of the tongue brushed for 1 minute with a 1% CHX gel; tonsils sprayed four times with 0.2% CHX; mouth rinse used twice daily for 1 minute with 0.2% CHX solution for 14 days	MD using plastic scalers and poly-etheretherketone-coated ultrasonic instruments	Yes	T: 6 C: 5 8 m/5 f	T: 22 C: 14	8

T = test group; C = control group; m = male; f = female; MD = mechanical debridement; OHI = oral hygiene instructions; aPDT = antimicrobial photodynamic therapy; CHX = chlorhexidine; CFU = colony-forming unit; PD = pocket depth; CAL = clinical attachment level; BoP = bleeding on probing; PI = plaque index; PS = plaque score; BI = bleeding index; BS = bleeding score; MMP = mucosal margin position; NA = not available.
*Statistically significant difference between test and control groups.

amplitude of clinical improvements achieved. Consequently, it was decided to generate the overall forest plots concerning the potential improvements achieved using adjunctive treatments without WMD values to display, without bias, any potential validity regarding adjunctive treatment approaches compared with the use of debridement alone. All these aspects should be taken into consideration when interpreting the results of this systematic review.

Agreements and Disagreements with Other Studies or Reviews

Peri-implant mucositis is primarily diagnosed in daily clinical practice and in most studies based on the presence of clinical signs of inflammation without progressive bone loss.[60] It is important to consider that peri-implant mucositis may never progress to peri-implantitis.[4] However, if peri-implant mucositis is left untreated and a supportive maintenance program is not established, the likelihood of developing peri-implantitis increases.[61]

While other studies with a similar design have been reported previously,[62,63] this systematic review included recently published studies, leading to an increase of the sample size (N = 24). Additionally, this review attempted to separate smokers and vapers/electronic cigarette users from nonsmokers or patients with unclear smoking status in the data analysis. This methodologic approach could be advantageous in exploring treatment outcomes within these distinct demographic groups.

The main findings of this review are consistent with those reported in previous similar studies,[63,64] showing minimal benefits of using adjunctive treatment in addition to debridement alone for the treatment of peri-implant mucositis. The meta-analyses did not reveal statistically significant differences for PD and BoP reduction in studies including nonsmokers or patients with unclear smoking status. Interestingly, one study[51] that involved the use of adjunctive aPDT showed an additional 2.3 mm of PD reduction and a decrease in oral yeast colonization at 3 months compared to values measured from peri-implant debridement alone. The authors of this report suggested that the observed antimicrobial effect was a result of the reactive oxygen species produced by the photosensitizer and the activating light source. However, it is worth noting that this study did not provide an oral hygiene program to the participants throughout the study period. As a result, poor plaque control was reported in the end of the study period for patients in the control group (peri-implant debridement as a monotherapy) compared to the adjunctive aPDT group, which may have largely influenced the results beyond the use of this adjunctive treatment.

For BoP reduction between the test and control groups, subgroup analyses showed that using certain oral probiotics,[32,37,50,52] such as *L reuteri* strains, contributed to a reduction in BoP for an average of 10.39% for nonsmokers or patients with unclear smoking status. Additionally, one study on the use of systemic

Treatment outcomes (differences)								
PD reduction (mm ± SD)	CAL gain (mm ± SD)	BoP reduction (%)	PI/PS reduction (± SD)	BI/BS reduction (± SD)	MMP gain (mm ± SD)	Complete resolution (%)	Microbiologic outcomes	Conclusions
T: 0.65 (0.55) C: 0.58 (0.21)	T: 0.50 (0.92) C: 0.57 (0.29)	T: 8 (19) C: 21 (32)	T: 1 (3) C: 19 (23) PS	T: 16 (25) C: 18 (60) BS	NA	NA	The microbiologic outcomes showed no significant reductions for implants and teeth in the total bacterial load after 8 months.	Adjunctive use of full-mouth approach with CHX in treating peri-implant mucositis did not show additional benefits compared to MD alone at 8 months.

azithromycin also showed an additional 22.80% reduction in BoP.[39] The authors of this study attributed the greater BoP reduction in the antibiotics group to higher standards of oral hygiene.[37] Hence, the indication of antibiotic therapy for treating peri-implant mucositis remains questionable and should be evaluated in the context of the broader risk associated with the development of antibiotic resistance. With respect to the promising 3-month BoP outcomes promoted by the adjunctive use of oral probiotics,[32,50] a possible explanation would be that peri-implant debridement is expected to disrupt the oral biofilm, thereby enhancing the effectiveness of adjunctive therapy. Nevertheless, one study[32] suggested that the beneficial effect of adjunctive oral probiotics on BoP reduction seemed to diminish after 3 months, while another study[50] reported an extended benefit of BoP reduction at 6 months. This difference was attributed to the genus and bacterial strain used and the delivery method (oral probiotics and topical application vs oral probiotics only).[50] However, high-level evidence on this therapeutic option is still very limited.

Although several studies reported that peri-implant mucositis could be halted with treatment, achieving complete disease resolution does not seem to be a predictable outcome.[4] We found that there is no statistically significant difference in the percentage of complete disease resolution between the control (debridement alone) and the test group (debridement plus adjunctive therapy). In fact, all the studies reporting this outcome reported that complete disease resolution was not consistently achieved. Moreover, most studies[29,35,40,41] only reached 30% to 40% complete disease resolution at the implant level. This result is in congruence with other similar studies[65,66] that concluded that complete disease resolution is an elusive outcome. Interestingly, one study[50] reported that a significantly higher chance (odds ratio = 5.20) of achieving complete disease resolution was associated with the use of adjunctive oral and topical probiotics when compared to debridement alone, whereas other studies failed to show any benefits of adjunctive regimens on complete disease resolution. Futures studies are needed to explore the potential of different therapeutic approaches to achieve complete resolution of peri-implant mucositis.

For smokers, although some evidence from individual studies[32,36] demonstrated a statistically significant difference in PD and BoP reduction, these improvements were very modest and did not achieve clinical significance. In a study[32] comparing treatment outcomes between smokers and nonsmokers, individuals with a daily smoking habit displayed poorer therapeutic outcomes than nonsmokers. This finding suggests that cigarette smoking compromises peri-implant soft tissue healing, regardless of whether peri-implant debridement is performed with or without adjunctive treatment.

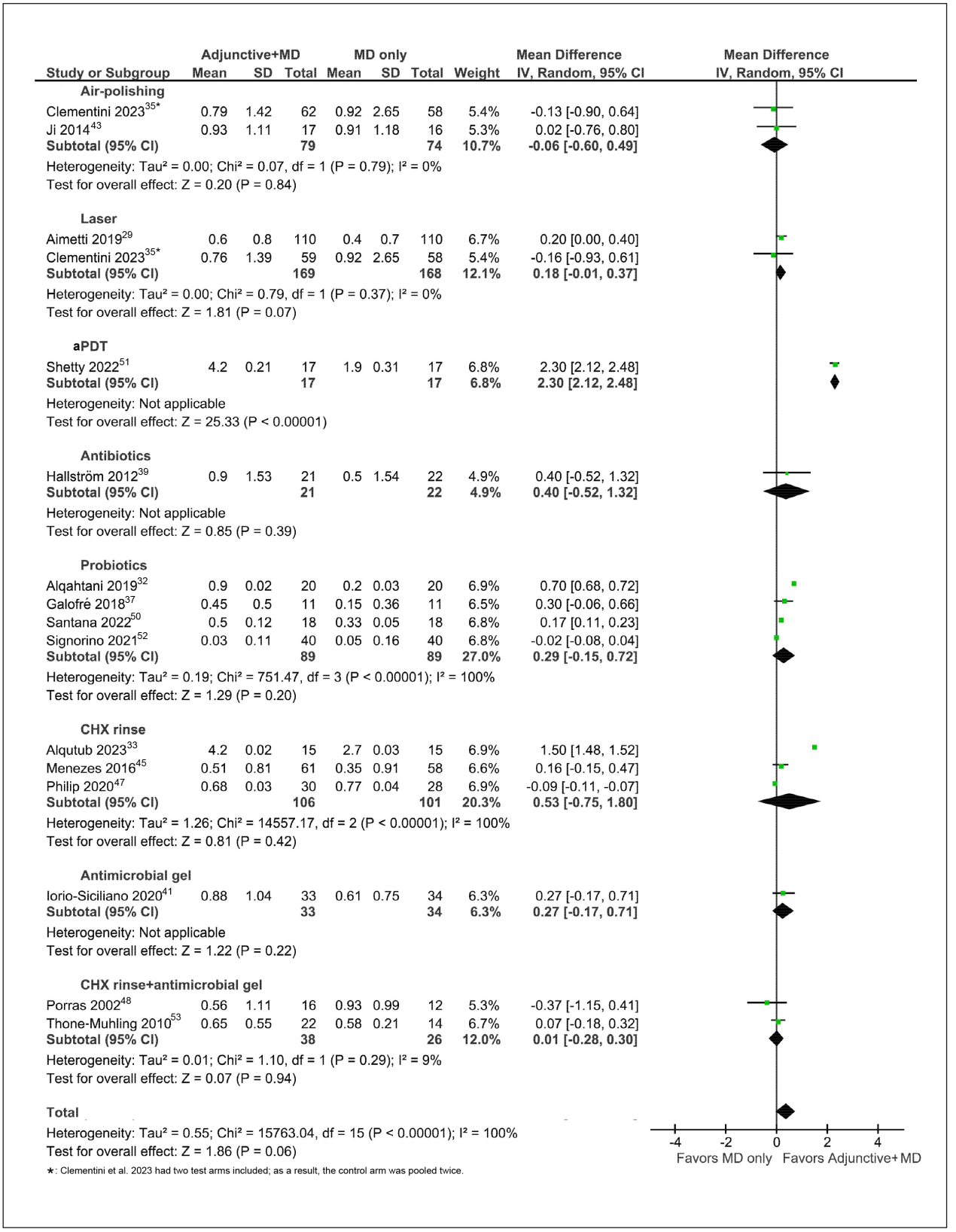


Fig 2a Meta-analysis of studies including nonsmokers or patients with unclear smoking status. Subgroup analyses were performed when data from at least two RCTs were available for analysis. For the comparison of PD reduction, no statistical significance was found for any of the subgroup comparisons.

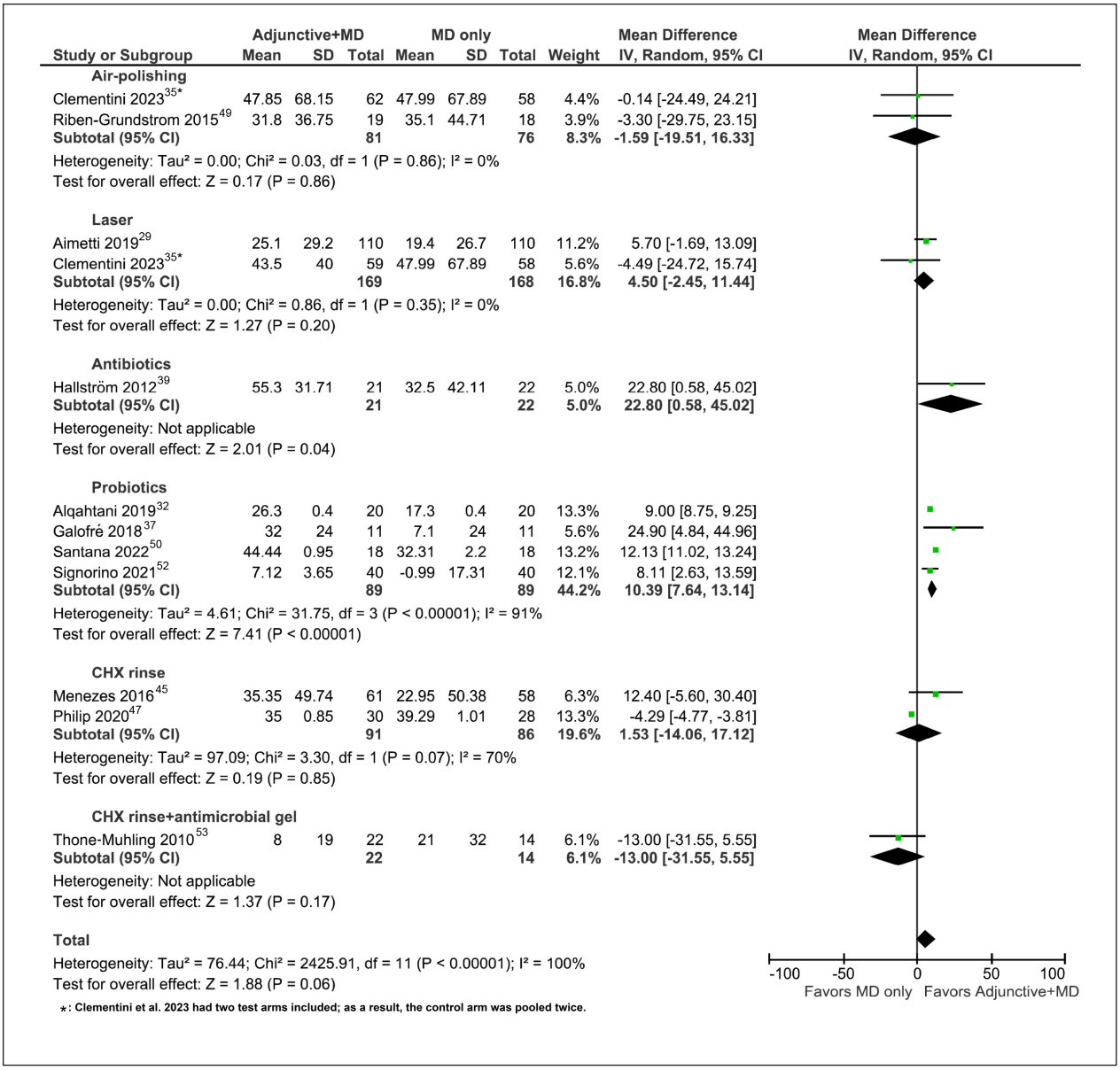


Fig 2b For the comparison of BoP reduction, the probiotic subgroup had a WMD of 10.39%, in favor of this treatment.

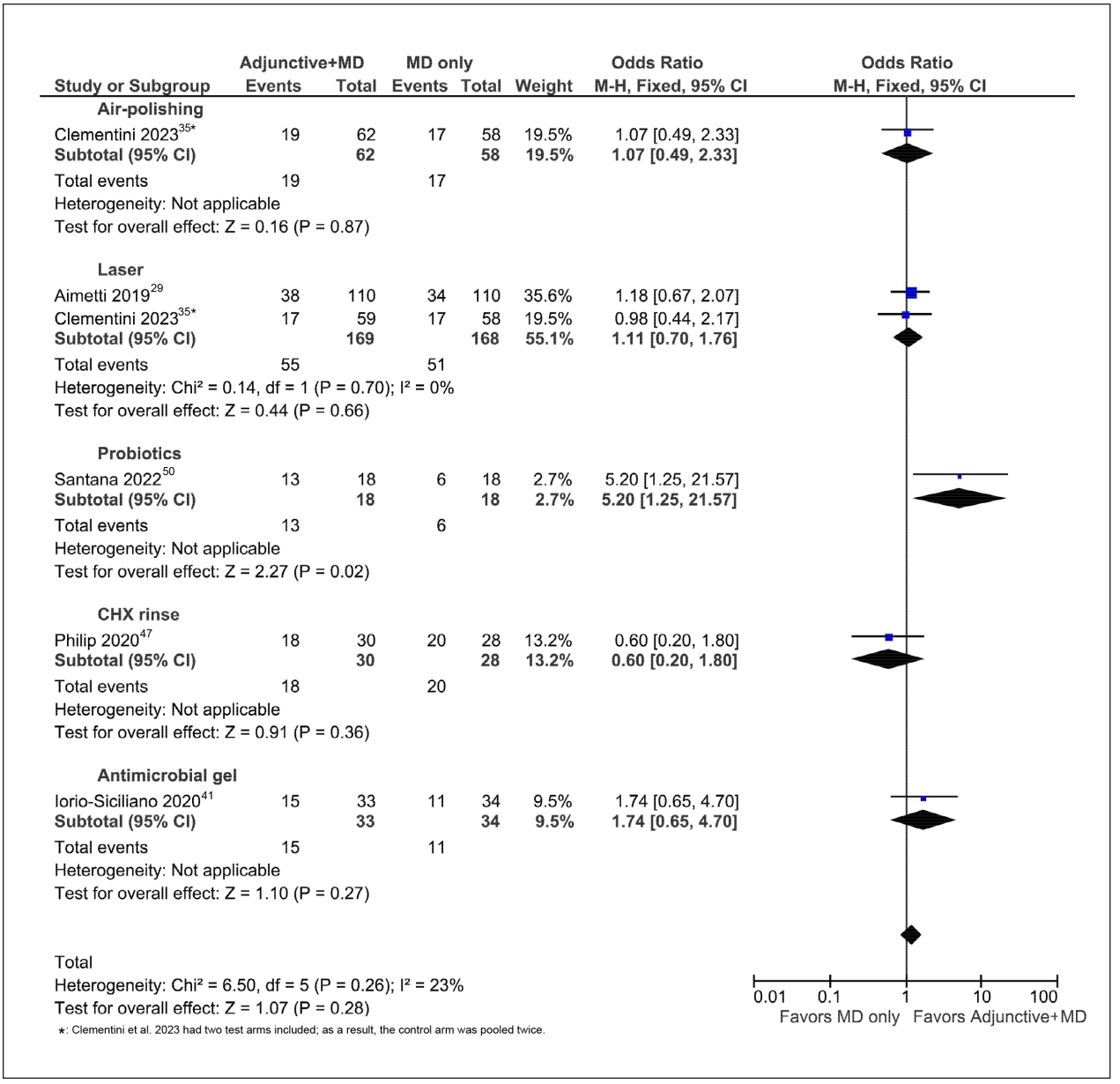
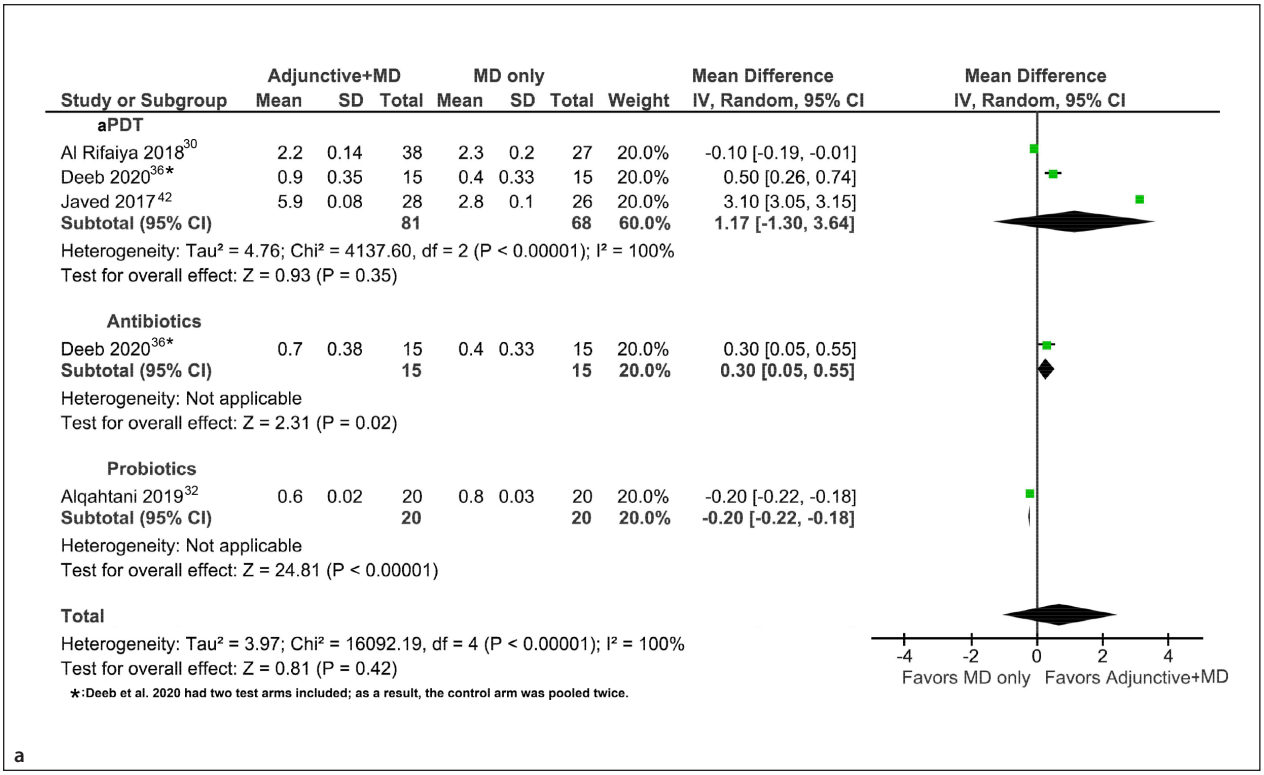
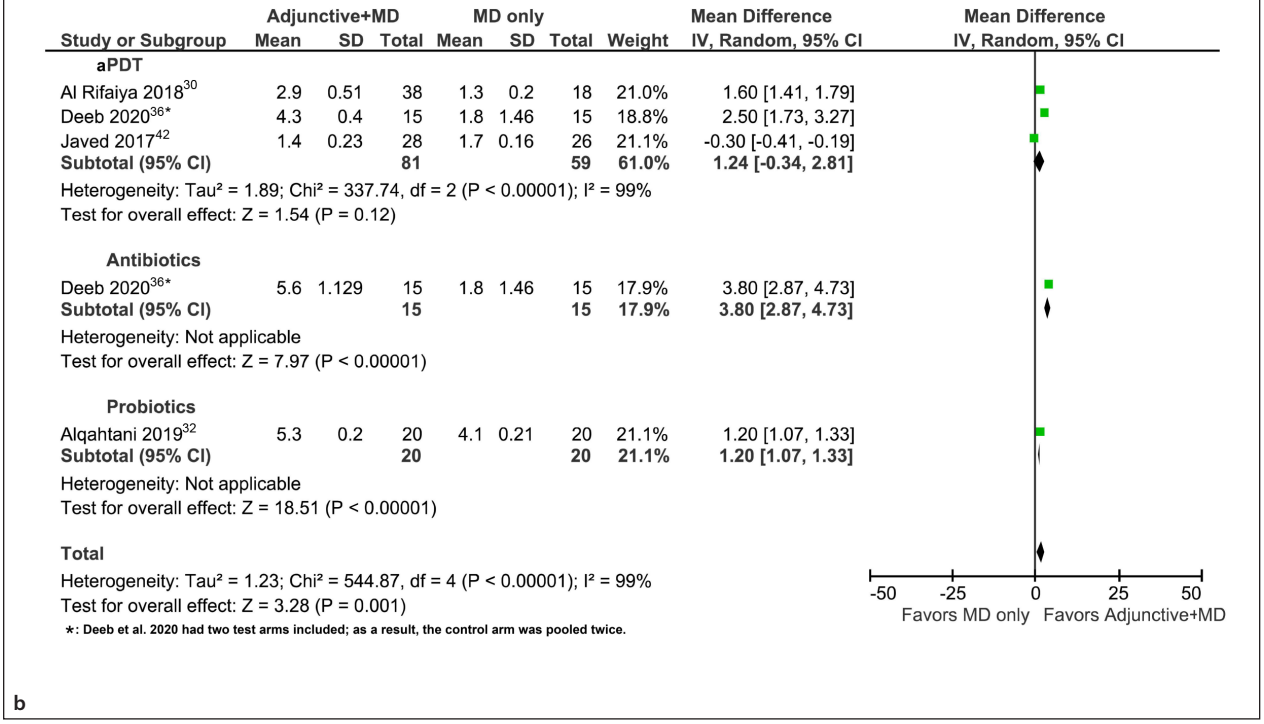


Fig 2c For complete disease resolution, the comparison between test and control groups did not render a statistically significant difference.



a



b

Fig 3 Meta-analysis for studies exclusively involving smokers or individuals using vapes/electronic cigarettes. Subgroup analyses were performed when data from at least two RCTs were available for analysis. *(a)* For the comparison of PD reduction, no statistical significance was found for any of the subgroup comparisons. *(b)* For the comparison of BoP reduction, no statistical significance was found for any of the subgroup comparisons.

CONCLUSIONS

Based on the findings of this systematic review, it can be concluded that:

- Peri-implant debridement as a monotherapy for the treatment of peri-implant mucositis generally results in clinical improvements to PD and BoP reduction.
- The use of adjunctive treatment modalities does not seem to provide a clinically significant therapeutic benefit compared to debridement alone, independent of the smoking status.
- Complete disease resolution is not consistently achieved regardless of the treatment modality.

Implications for Clinical Practice and Future Research

Due to the limited amount of high-level evidence on the effect of some adjunctive treatments, future studies are necessary to explore the potential benefits of these therapies (eg, laser therapy, aPDT, probiotic-related therapies, and systemic antibiotics) in enhancing the clinical outcomes promoted by mechanical debridement for the treatment of peri-implant mucositis. Additionally, future studies should explore the effect of implant surface–related factors, including topographic variability, surface alterations, and suboptimal decontamination, on treatment outcomes. Finally, it is worth noting that the effect of changes in prosthetic design on the response to therapy was not considered in any of the selected studies. This is a relevant aspect that may partially explain the observations regarding complete disease resolution in the selected studies, and therefore it should be included in future studies on the treatment of peri-implant diseases related to dysbiotic microbial biofilm accumulation.

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G.H.L and L.C.: conceptualization, formal analysis, investigation, methodology, and writing and preparation of the original draft; Y.R. and G.A.O: validation, supervision, and writing/editing of the review.

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APPENDIX

The search terms used in MEDLINE/PubMed were:
("peri-implant"[All Fields] AND ("mucositis"[MeSH Terms] OR "mucositis"[All Fields])) AND ((("glycine"[MeSH Terms] OR "glycine"[All Fields]) OR ("chlorhexidine"[MeSH Terms] OR "chlorhexidine"[All Fields]) OR ("lasers"[MeSH Terms] OR "lasers"[All Fields] OR "laser"[All Fields]) OR ("triclosan"[MeSH Terms] OR "triclosan"[All Fields]) OR ("probiotics"[MeSH Terms] OR "probiotics"[All Fields] OR "probiotic"[All Fields])) AND implant[All Fields])

The search terms used in EMBASE were:
('peri-implant':ab,ti OR 'peri-implant':de) AND ('mucositis':de OR 'mucositis':ab,ti) AND ((('glycine':de OR 'glycine':ab,ti) OR ('chlorhexidine':de OR 'chlorhexidine':ab,ti) OR ('lasers':de OR 'lasers':ab,ti OR 'laser':ab,ti) OR ('triclosan':de OR 'triclosan':ab,ti) OR ('probiotics':de OR 'probiotics':ab,ti OR 'probiotic':ab,ti)) AND 'implant':ab,ti,de)

Appendix Fig 1 Search terms used in MEDLINE/PubMed and EMBASE databases.

Appendix Table 1 List of Excluded Articles

Reason for exclusion	Authors (year of publication)
< 3-month follow-up	Mongardini et al[18] (2017) Sargolzaei et al[24] (2022) Zeza et al[28] (2018)
< 10 patients per group	Schenk et al[25] (1997)
No mechanical debridement group as control	Bunk et al[13] (2020) De Siena et al[15] (2013) Pena et al[19] (2019) Pourabbas et al[20] (2023) Ramberg et al[21] (2009) Sánchez-Martos et al[22] (2020) Tenore et al[26] (2020) Tütüncüoğlu et al[27] (2022)
No differentiation between healthy and peri-implant mucositis patients	Flichy-Fernández et al[16] (2015) Sanchez-Perez et al[23] (2020)
No differentiation between patients with peri-implant mucositis and peri-implantitis	Lerario et al[17] (2016)
Secondary data analysis	De Melo Menezes et al[14] (2021)

Appendix Table 2 Risk Assessment of Publication Bias for the Included RCTs

Study	Bias arising from the randomization process	Bias due to deviation from the intended intervention	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall
Aimetti et al[29] (2019)	Low	Low	Low	Low	Low	Low
Al Rifaiy et al[30] (2018)	Low	Low	Low	Low	Low	Low
Al-Sowygh et al[31] (2017)	Low	Low	Low	High	Low	High
Alqahtani et al[32] (2019)	Low	Low	Low	Low	Low	Low
Alqutub et al[33] (2023)	Low	Low	Low	Low	Low	Low
Alzoman et al[34] (2020)	Low	Low	Low	Low	Low	Low
Clementini et al[35] (2023)	Low	Low	Low	Low	Low	Low
Deeb et al[36] (2020)	Low	Low	Low	Some concerns	Low	Some concerns
Galofré et al[37] (2018)	Low	Low	Low	Low	Low	Low
Hallström et al[38] (2017)	Low	Low	Low	Low	Low	Low
Hallström et al[39] (2012)	Low	Low	Low	Low	Low	Low
Heitz-Mayfield et al[40] (2011)	Low	Low	Low	Some concerns	Low	Some concerns
Iorio-Siciliano et al[41] (2020)	Low	Low	Some concerns	Low	Low	Some concerns
Javed et al[42] (2017)	Low	Low	Some concerns	Some concerns	Low	Some concerns
Ji et al[43] (2014)	Some concerns	Low	Low	High	Low	High
Lazar et al[44] (2023)	Some concerns	Low	Low	Some concerns	Some concerns	High
Menezes et al[45] (2016)	Low	Low	Low	Low	Low	Low
Philip et al[46] (2022) & Philip et al[47] (2020)	Low	Low	Some concerns	Low	Low	Some concerns
Porras et al[48] (2002)	Some concerns	Low	Low	High	High	High
Riben-Grundstrom et al[49] (2015)	Low	Low	Low	Some concerns	Low	Some concerns
Santana et al[50] (2022)	Low	Low	Low	Low	Low	Low
Shetty et al[51] (2022)	Some concerns	Low	Low	Low	Low	Some concerns
Signorino et al[52] (2021)	Low	Low	Low	Low	Low	Low
Thone-Muhling et al[53] (2010)	High	Low	Some concerns	High	Low	High