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SYSTEMATIC REVIEW

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Non-surgical therapy of peri-implant mucositis—Mechanical/physical approaches: A systematic review

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Abstract

Aim: To study in humans with peri-implant mucositis the efficacy of (Q1) mechanical/physical instrumentation over oral hygiene instructions alone; (Q2) any single mode of mechanical/physical instrumentation over others; (Q3) combinations of mechanical/physical instrumentation over single modes; and (Q4) repetitions of mechanical/physical instrumentation over single administration.

Materials and Methods: Randomized clinical trials (RCTs) fulfilling specific inclusion criteria established to answer the four PICOS questions were included. A single search strategy encompassing the four questions was applied to four electronic databases. Two review authors independently screened the titles and abstracts, carried out full-text analysis, extracted the data from the published reports and performed the risk of bias assessment through the RoB2 tool of the Cochrane Collaboration. In case of disagreement, a third review author took the final decision. Treatment success (i.e., absence of bleeding on probing [BoP]), BoP extent and BoP severity were considered as the implant-level outcomes of critical importance for the present review.

Results: A total of five papers reporting on five RCTs, involving 364 participants and 383 implants, were included. Overall, treatment success rates after mechanical/physical instrumentation ranged from 30.9% to 34.5% at 3 months and from 8.3% to 16.7% at 6 months. Reduction in BoP extent was 19.4%–28.6% at 3 months, 27.2%–30.5% at 6 months and 31.8%–35.1% at 12 months. Reduction in BoP severity was 0.3–0.5 at 3 months and 0.6–0.8 at 6 months. Q2 was addressed in two RCTs, which reported no differences between glycine powder air-polishing and ultrasonic cleaning, as well as between chitosan rotating brush and titanium curettes. Q3 was addressed by three RCTs, which showed no added effect of glycine powder air-polishing over the use of ultrasonic and of diode laser over ultrasonic/curettes. No RCTs were identified that answered Q1 and Q4.

Conclusions: Several mechanical/physical instrumentation procedures including curettes, ultrasonics, lasers, rotating brushes and air-polishing are documented; however, a beneficial effect over oral hygiene instructions alone or superiority over other procedures could not be demonstrated. Moreover, it remains unclear whether

combinations of different procedures or their repetition over time may provide additional benefits.
(CRD42022324382)

KEYWORDS
dental implants, disease resolution, guidelines, peri-implant diseases, randomized controlled trial

Clinical Relevance

Scientific rationale for study: No clinical guidelines are still available to guide clinicians on mechanical/physical therapies of peri-implant mucositis.

Principal findings: Several mechanical/physical instrumentation procedures including curettes, ultrasonics, lasers, rotating brushes and air-polishing are documented; however, their efficacy over no treatment or superiority over other procedures in terms of treatment success and bleeding on probing extent/severity is still unproven. Moreover, it remains unclear whether combinations of different procedures or their repetition over time may provide additional benefits.

Practical implications: Owing to the risk of progression into peri-implantitis, clinicians are strongly recommended to diagnose and treat peri-implant mucositis. However, there is not enough evidence to support the use of any physical/mechanical instrumentation protocol over others or over oral hygiene instructions alone. Therefore, definitive randomized clinical trials are needed.

1 | INTRODUCTION

Peri-implant mucositis is a highly prevalent disease characterized by inflammation of the peri-implant mucosa without loss of the supporting bone (Berglundh, Armitage, et al., 2018; Ferreira et al., 2006; Koldsland et al., 2010; Romandini et al., 2019; Romandini, Lima, et al., 2021; Wada et al., 2019). Its main clinical sign is the presence of bleeding on (gentle) probing (BoP) (Berglundh, Armitage, et al., 2018). There is evidence from experimental human studies that peri-implant mucositis is caused by biofilm accumulation and that its resolution may occur with adequate biofilm control (Meyer et al., 2017; Salvi et al., 2012; Schincaglia et al., 2017). If untreated, peri-implant mucositis may progress into peri-implantitis, which is further characterized by the loss of supporting bone and may ultimately lead to implant loss (Costa et al., 2012; Derks et al., 2016). Treatment of peri-implant mucositis is therefore considered the strongest primary preventive measure for peri-implantitis (Jepsen et al., 2015).

Owing to its nature, the treatment of peri-implant mucositis is focused on the disruption of the dental implant biofilm and aimed at achieving treatment success/disease resolution (i.e., absence of BoP), or at least a reduction in the number of bleeding sites (i.e., BoP extent) or of its severity (e.g., modified bleeding index or mBI; Mombelli et al., 1987; Renvert et al., 2018). Therefore, after a patient's behavioural phase including oral hygiene instructions (OHI), the affected implants usually undergo non-surgical instrumentation, which may be realized through mechanical (e.g., curettes, ultrasonics, air-polishing) and/or physical (e.g., laser) approaches (Baima et al., 2022; Renvert et al., 2019). Adjunctive measures (e.g., antiseptics) may also be used (Jepsen et al., 2015).

When it comes to mechanical/physical therapies, no guidelines are available for clinicians yet. The added benefit of professional mechanical/physical instrumentation as compared to OHI alone is not known. Furthermore, there is no consensus on the most effective means of professional mechanical/physical treatment of peri-implant mucositis to date, or on whether combinations may provide added benefits. Finally, the repetition of non-surgical instrumentation may be of relevance for affected implants refractory to a first therapeutic attempt. Therefore, the present systematic review aimed at answering the following four focused questions:

Q1. In human subjects suffering from peri-implant mucositis (P), has professionally administered non-surgical mechanical/physical therapy (I) any effect over OHI alone (C), in terms of clinical/radiographic parameters and invasiveness (O), as shown in randomized clinical trials (RCTs) (S)?

Q2. In human subjects suffering from peri-implant mucositis (P), is any single mode of professionally administered non-surgical mechanical/physical therapy (I) superior to other single modes of professionally administered non-surgical mechanical/physical therapy (C), in terms of clinical/radiographic parameters and invasiveness (O), as shown in (RCTs) (S)?

Q3. In human subjects suffering from peri-implant mucositis (P), are combinations of treatment modes of professionally administered non-surgical mechanical/physical therapy (I) superior to single modes of professionally administered non-surgical mechanical/physical therapy (C), in terms of clinical/radiographic parameters and invasiveness (O), as shown in (RCTs) (S)?

Q4. In human subjects suffering from peri-implant mucositis (P), does repetition of professionally administered non-surgical mechanical/physical therapy (I) provide added benefits over single administration (C), in terms of clinical/radiographic parameters and invasiveness (O), as shown in (RCTs) (S)?

2 | MATERIALS AND METHODS

This systematic review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) 2020 guidelines (Page et al., 2021). A detailed protocol was designed before the start of the study and registered at PROSPERO (CRD42022324382).

2.1 | Eligibility criteria

The eligibility criteria of this systematic review were organized by the PICOS acronym.

(P) *Participants*: Human subjects with dental implants suffering from peri-implant mucositis, diagnosed with a clear case definition. Peri-implant mucositis was defined as the presence of BoP and/or suppuration on probing (SoP), without bone loss exceeding 0.5 mm beyond crestal bone level changes resulting from initial bone remodelling, regardless of probing pocket depth (PPD) values (Berglundh, Armitage, et al., 2018). In the absence of baseline radiographs (i.e., 0–1 year after loading), a bone level of <2 mm from the top of the intra-osseous part of the implant was considered as the reference threshold (Romandini, Berglundh, et al., 2021).

(I) *Interventions*: Considered interventions varied according to the specific focused question, as follows:

Q1. Any professionally administered non-surgical mechanical/physical therapy, alone or in combination, delivered only in one session or repeatedly;

Q2. Any professionally administered non-surgical mechanical/physical mode of therapy applied alone, delivered only in one session or repeatedly;

Q3. Any combination of professionally administered non-surgical mechanical/physical therapies, delivered only in one session or repeatedly;

Q4. Any professionally administered non-surgical mechanical/physical therapy, alone or in combination, repeated at multiple time points.

(C) *Comparisons*: Considered comparisons varied according to the specific focused question, as follows:

Q1. OHI alone;

Q2. Any possible alternative professionally administered non-surgical mechanical/physical mode of therapy administered alone, delivered only in one session or repeatedly;

Q3. Only one of the same professionally administered non-surgical mechanical/physical mode of therapy administered alone, delivered only in one session or repeatedly;

Q4. Any professionally administered non-surgical mechanical/physical therapy, alone or in combination, applied only in one session.

(O) *Outcome measures*: At least one of the following outcomes of interest:

Implant-level outcomes. Treatment success; BoP extent, BoP severity, PPD, soft tissue level, onset of peri-implantitis, bone loss, need for further treatment.

Patient-level outcomes. Patient-reported outcome measures (PROMs) (i.e., intra-operative discomfort, post-operative discomfort, pain, swelling, bleeding, quality of life), economical costs, treatment time, adverse events.

(S) *Studies*: Since they best capture efficacy of healthcare interventions, only RCTs were included. They should have at least 3 months follow-up after the first intervention, either with a parallel or a split-mouth design, been published in peer-reviewed journals and have a minimum of 10 patients per arm. No studies were excluded based on the date of publication. Only studies that provided a clear description of the intervention(s) and comparison(s) rendered were considered. Studies applying additional non-mechanical/physical (e.g., chemical therapies) or non-professionally administered (e.g., behavioural interventions) therapies only in one group were excluded.

2.2 | Information sources

A committed academic librarian performed a single systematic search in four electronic databases (Medline via Ovid, Embase via Ovid, Cochrane Database of Controlled Trials [Wiley], Scopus [Elsevier]) from outset to 23 March 2022, openly looking at human RCTs published on peri-implant mucositis treatment. The complete search strategies are reported in the Appendix S1. Owing to time restrictions for the preparation of this systematic review, reference lists of included studies, expert consultation and grey literature searches were not performed, and only studies reported in English were included.

2.3 | Selection process

The titles and abstracts (when available) of all electronically identified studies were uploaded in Covidence (https://www.covidence.org/) and independently screened by two reviewers (Mario Romandini, Anders Verket). The full reports of articles potentially meeting the inclusion criteria identified during electronic screening were then evaluated independently by the same two review authors (Mario Romandini, Anders Verket) to make the final decision. Any disagreement during the study selection process was solved through discussion with a third reviewer (Odd Carsten Koldsland). The reasons for excluding studies after full-text evaluation were recorded. The inter-reviewer agreement (percentage of agreement and kappa correlation coefficient) of the screening and full-text analysis phases was calculated.

2.4 | Data extraction and management

2.4.1 | Data collection

Data from the included studies were extracted independently and in duplicate by two review authors (Dagmar Bunæs, Odd Carsten Koldsland) with the use of predefined data extraction forms. All the extracted data and eventual disagreements were jointly discussed in presence of a third reviewer (Mario Romandini) until agreement was reached. Whenever needed, authors from the included RCTs were contacted.

For each RCT the following data were extracted:

- General information. First author; year of publication; country.
- Methods. Study design (i.e., parallel or split-mouth, clustering); settings (university, hospital, private practice); number of centres; peri-implant mucositis case definition; inclusion and exclusion criteria; follow-up length.
- Participants. Total number of randomized participants and implants; age (mean); gender (female, male); periodontal status (no periodontitis, periodontitis); smoking status (non-smokers, former smokers and smokers).
- Interventions and comparisons. PICOS questions included (Q1, Q2, Q3, Q4); number of study groups; for each of the study groups: intervention(s), number of allocated (participants and implants), number of dropouts (participants and implants), repetition (delivered only in one session or repeatedly); non-mechanical or whole dentition interventions common to all study groups (e.g., information and motivation, OHI, antiseptics, etc.).
- Outcomes and results of interest. For each outcome considered (see Section 2.4.2): collected (yes, no), definition and assessment methods (periodontal probe type, number of sites considered), available time points, estimates. Absolute values (i.e., not changes with respect to baseline) were considered at all available time points from 3 months onwards. Whenever possible, intention-to-treat data were selected.
- Study funding, and possible conflicts of interest.
- Risk of bias (see Section 2.5).

2.4.2 | Outcomes definitions

Treatment success, BoP extent and BoP severity were considered as the implant-level outcomes of critical importance for the present systematic review.

Rather, the following outcomes were regarded as important:

Implant level: PPD, soft tissue level, onset of peri-implantitis, bone loss, need for further treatment.

Patient level: PROMs (i.e., intra-operative discomfort, post-operative discomfort, pain, swelling, bleeding, quality of life), economical costs, treatment time, adverse events.

Owing to heterogeneity in the terminology reported in the literature, the following definitions were employed for the three outcomes of critical importance:

Treatment success (i.e., disease resolution) was defined as the absence of BoP in all sites around the previously affected dental implant.

BoP extent was defined as either the percentage or the numbers of BoP+ sites around a dental implant.

BoP severity was defined as the intensity of BoP around a dental implant (e.g., mBI; Mombelli et al., 1987; Renvert et al., 2018). It could be presented either as mean or worst value among the considered peri-implant sites.

2.5 | Assessment of risk of bias in included studies

The risk of bias of the included studies was assessed in duplicate as part of the data extraction process, using the version 2 of the Cochrane risk-of-bias tool (RoB2) for randomized trials (Sterne et al., 2019). The risk of bias was evaluated separately for each one of the three outcomes of critical importance (treatment success, BoP extent, BoP severity), in relation to the evaluation of the effect of assignment to the interventions at baseline (i.e., intention to treat). The overall judgement of the risk of bias was then done as follows:

Low risk of bias. Low risk of bias for all domains for the specific outcome.

Some concerns. Some concerns in at least one domain for the specific outcome, but not high risk of bias evaluations.

High risk of bias. High risk of bias in at least one domain, or some concerns for multiple domains in a way that substantially lowers confidence in the results for the specific outcome.

2.6 | Unit of analyses and measures of effect of interventions

Depending on the nature of the variable, either the implant (e.g., reduction in the extent of BoP) or the patient (e.g., PROMs) was considered as the statistical unit. For each study, group-specific results were expressed as means (standard deviations, SD) for the continuous outcomes and as number of events (percentage, %) for the binary ones, of absolute values at the specific time points. Inter-group comparison results were expressed for each study in terms of either differences in means (MDs, for continuous outcomes) with standard errors (SEs) or odds ratios (ORs, for binary outcomes) with 95% confidence intervals (CIs), of the absolute values at the specific time points. Adjustments for clustering (i.e., multiple implants per patient) and/or design (i.e., split mouth) were performed whenever appropriate.

2.7 | Data synthesis

Data synthesis was meant to be carried out, depending on data availability, using STATA version 13.1 software (StataCorp LLC, Texas, USA) with statistical significance level set in advance on *p*-values <.05. In presence of at least two studies for each comparison, inter-group meta-analyses were to be realized using the random effects method and the generic inverse variance approach. These meta-analyses were to be reported as MDs or ORs with 95% CI and, in presence of at least three studies, also with 95% prediction interval (95% PI) (Riley et al., 2011). Specific sub-group and sensitivity analyses, network meta-analyses and meta-regressions were to be considered depending on the availability of data. Inter-study heterogeneity was to be assessed in all meta-analyses by

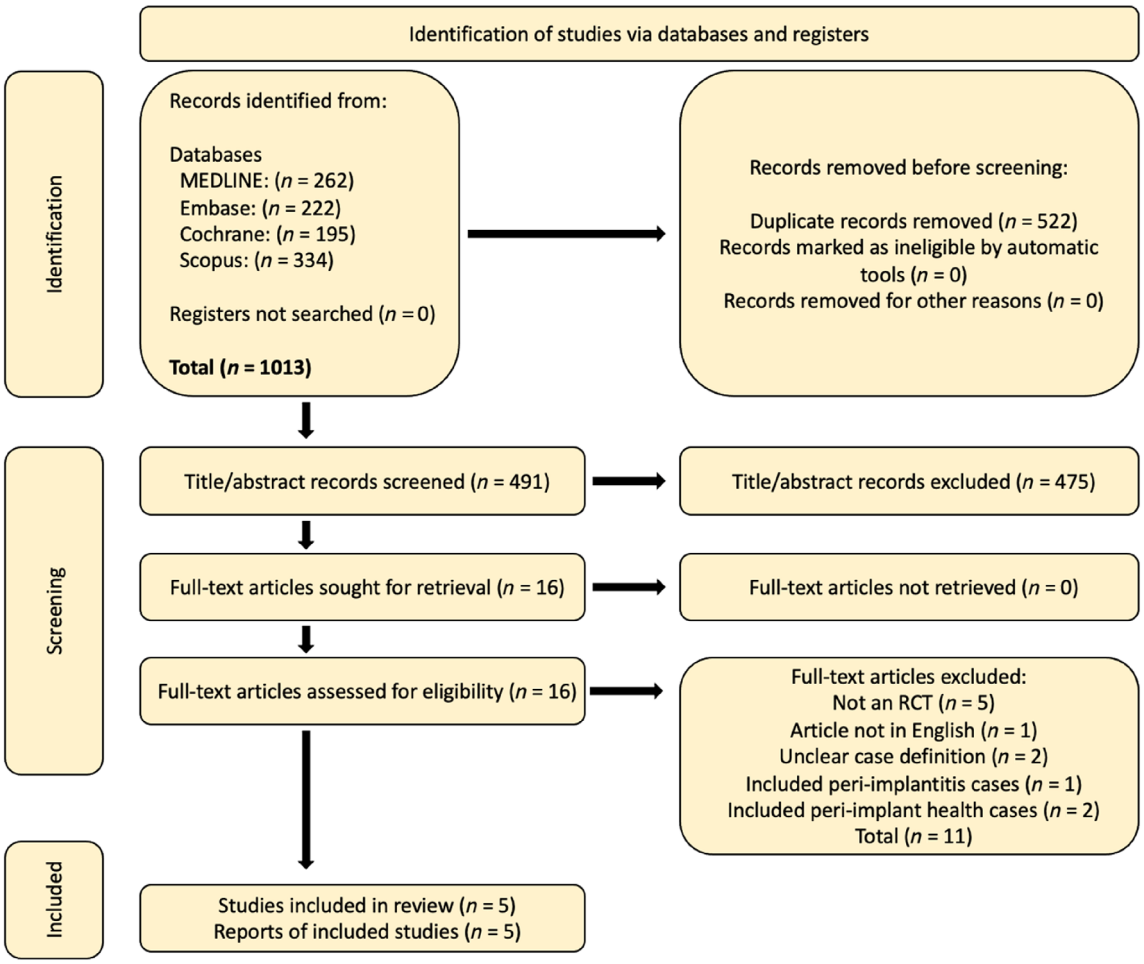

FIGURE 1 Flow-chart of the study selection process.

carefully examining the characteristics of the included studies, by inspecting the forest plots and by calculating Cochran's test, τ^2 and I^2 statistics.

3 | RESULTS

3.1 | Study selection

Figure 1 shows the flow-chart of the selection process. The electronic search resulted in the identification of 491 titles after removal of duplicates. Of these, 475 were discarded after title- and abstract-screening (agreement = 98.0%; κ = 0.68, 95% CI: 0.49–0.87). Eleven out of the remaining 16 articles were excluded after full-text analysis (reasons for exclusion reported in Table S1) (agreement = 93.3%; κ = 0.86, 95% CI: 0.59–1.00). Finally, five publications reporting results from five RCTs and a total of 364 participants (383 implants) met the inclusion criteria and were then included in this systematic review (Table 1) (Aimetti et al., 2019; Ji et al., 2014; Riben-Grundstrom et al., 2015; Sánchez-Martos et al., 2020; Wohlfahrt et al., 2019).

3.2 | Characteristics of the included studies

3.2.1 | Methods and participants

Table S2 gives details about the methods and participants of the included studies. Four of the included trials had a parallel design (in one case with clustering), while the remaining one was split-mouth with clustering (Wohlfahrt et al., 2019). All included trials were monocentric carried out in university settings. Peri-implant mucositis case definitions always included at least the presence of BoP; only one study did not include also the presence of a PPD ≥ 4 mm (Sánchez-Martos et al., 2020). Three studies considered the absence of bone loss compared with reference radiographs (Ji et al., 2014; Sánchez-Martos et al., 2020; Wohlfahrt et al., 2019), one study considered bone levels ≤2 mm (Riben-Grundstrom et al., 2015) and the remaining one considered bone loss or bone levels depending on the availability of baseline readings (Aimetti et al., 2019).

The longest follow-up was 3 months following the first mechanical/physical intervention in three RCTs (Aimetti et al., 2019; Ji et al., 2014; Sánchez-Martos et al., 2020), while in the remaining ones it was 6 (Wohlfahrt et al., 2019) and 12 months (Riben-Grundstrom et al., 2015).

TABLE 1 General characteristics of the included studies.

Reference	Study design	Longest follow-up	Randomized - participants (implants)	PICOS question(s)	Intervention(s)	Comparison(s)	Treatment success rate (implant level)	BoP extent at last available follow-up (implant level)	BoP severity at last available follow-up (implant level)	Additional implant-/patient-level outcomes collected	Funding and possible conflicts of interest
Ji et al. (2014)	Parallel, (with clustering)	3 months	24 (33)[a]	Q3	Ultrasonic (carbon-fibre tip) + glycine powder air-polishing	Ultrasonic (carbon-fibre tip)	NR	NR	**3 months**[d] *Comparison*: 1.0 (SD = 0.85) *Intervention*: 1.1 (SD = 0.58) MD = 0.1 (SE = 0.30)	PPD	None reported
Riben-Grundstrom et al. (2015)	Parallel	12 months	37 (37)	Q2	Glycine powder air-polishing	Ultrasonic (plastic coated tip)	NR	**12 months**[b] *Comparison*: 18.6% (SD = 27.1) *Intervention*: 12.1% (SD = 16.1) MD = -6.5 (SE = 7.43)	NR	Soft tissue level	Funding from EMS
Wohlfahrt et al. (2019)	Split-mouth (with clustering)	6 months	12 (NR)	Q2	Chitosan rotating brush	Titanium curettes	**6 months** *Comparison*: 2 out of 12 (16.7%) *Intervention*: 1 out of 12 (8.3%) OR = 0.45 (95% CI 0.04, 5.81)[f]	NR	**6 months**[e] *Comparison*: 0.74 (SD = 0.80) *Intervention*: 0.70 (SD = 0.70) MD = -0–05 (SE = 0.31)[f]	PPD, bone loss, intra-operative morbidity	The first author is inventor, patent holder and shareholder of the tested intervention
Aimetti et al. (2019)	Parallel	3 months	220 (220)	Q3	Ultrasonic (carbon fibre tip) + curettes (titanium-coated) + biostimulation for 60 s at 0.7 W in continuous wave (frequency 20 Hz, fluence 1 J/cm^2) + Diode laser 980-nm	Ultrasonic (carbon fibre tip) + curettes (titanium-coated) + biostimulation for 60 s at 0.7 W in continuous wave (frequency 20 Hz, fluence 1 J/cm^2) + Sham laser use	**3 months** *Comparison*: 34 out of 110 (30.9%) *Intervention*: 38 out of 110 (34.5%) OR = 1.18 (95% CI 0.67, 2.07)	**3 months**[b] *Comparison*: 26.8% (SD = 23.0) *Intervention*: 23.2% (SD = 23.5) MD = -3.6 (SE = 3.14)	NR	PPD, soft tissue level	None reported
Sánchez-Martos et al. (2020)	Parallel	3 months	69 (69)	Q3	Ultrasonic (plastic tip) + Plastic curettes + Diode laser 810-nm	Ultrasonic (plastic tip) + Plastic curettes + Sham laser use	NR	**3 months**[c] *Comparison*: 0.57 (SD = 0.28) *Intervention*: 0.26 (SD = 1.17) MD = -0.31 (SE = 0.06)[g]	NR	PPD, soft tissue level	None reported

Abbreviation: CI, confidence interval; MD, difference in means; NR, not reported; OR, odds ratio; PPD, probing pocket depth; Q, question; SD, standard deviation; SE, standard error.
Note: Group-specific results for continuous outcomes are reported as mean (SD), while binary data are reported as number of events (%) per group at last available follow-up. Inter-group comparison estimates are reported as MD (SE) for the continuous outcomes and as OR (SE) for the binary ones. Detailed information on methods and participants, interventions and comparisons, implant- and patient-level outcomes/results is reported in Tables S2–S5, respectively.
[a]26 randomized, 2 dropouts without any reported information.
[b]BoP extent was measured as % of bleeding sites around each implant.
[c]BoP extent was measured as number of bleeding sites around each implant.
[d]BoP severity was measured as follows (Mombelli et al., 1987; Renvert et al., 2018): 0 = no bleeding; 1 = point of bleeding; 2 = line of bleeding; 3 = drop of bleeding. Implant-level results were not reported. Owing to the study design (parallel with clustering), patient-level results were considered acceptable and so reported in the table.
[e]BoP severity was measured as follows: 0 = no bleeding, 1 = isolated spots, minimal bleeding, 2 = blood forming a confluent red line on the margin and 3 = heavy or profuse bleeding.
[f]95% CI not adjusted for clustering and split-mouth design.
[g]Statistically significant (p <.05).

Sample size varied from 12 (Wohlfahrt et al., 2019) to 220 participants (Aimetti et al., 2019). All studies but one included both current smokers and non-smokers (Ji et al., 2014).

3.2.2 | Interventions and comparisons

Table S3 provides detailed information on the interventions and comparisons retrieved from the included RCTs. All the trials had two study groups, one comparison and one intervention.

Ji et al. (2014) studied the added effect of glycine powder air-polishing over mechanical instrumentation through ultrasonics with carbon-fibre tips delivered only in one session. OHI, as well as supra- and sub-gingival instrumentation of the remaining dentition, were provided in both groups after baseline examination.

Riben-Grundstrom et al. (2015) compared the use of glycine powder air-polishing alone with mechanical instrumentation through an ultrasonic device with a plastic-coated tip. Both the intervention and the comparison were repeated at 3 and 6 months. At 9 and 12 months' visits, only supragingival maintenance was performed on the whole dentition. OHI were provided after baseline examination and repeated every 3 months.

Wohlfahrt et al. (2019) compared mechanical instrumentation with chitosan oscillating brush with the use of titanium curettes. Both the intervention and the comparison were repeated at 3 months. OHI, as well as periodontal treatment in periodontitis patients, were provided prior to the baseline examination, since plaque-free implants were required for inclusion. Sub-marginal irrigation with sterile saline was employed in both groups after mechanical instrumentation.

Two studies (Aimetti et al., 2019; Sánchez-Martos et al., 2020) tested the added effect of laser therapy (vs. sham laser use) over mechanical instrumentation made by means of a combination of ultrasonic device (carbon-fibre or plastic tips, respectively) and curettes (titanium-coated or plastic, respectively). While Aimetti et al. (2019) used adjunctive laser therapy before the mechanical instrumentation, Sánchez-Martos et al. (2020) used it after. In both studies, the interventions and comparisons were applied in one session only. Aimetti et al. (2019) tested a 980-nm diode laser. Common interventions among groups included sub-marginal irrigation with 3% hydrogen peroxide solution for 10 s; biostimulation for 60 s at 0.7 W in continuous wave; OHI at baseline, 1 and 3 months; supra- and sub-gingival instrumentation on the remaining dentition at baseline; and supra-marginal maintenance of the study implants at 1 and 3 months (Aimetti et al., 2019). Sánchez-Martos et al. (2020) tested an 810-nm Fox diode laser; both study groups also received OHI and sub-marginal irrigation with a 0.12% chlorhexidine/ 0.05% cetylpyridinium chloride solution.

3.2.3 | Outcomes considered

Only two RCTs reported treatment success rates at implant level (Aimetti et al., 2019; Wohlfahrt et al., 2019), while BoP extent was reported in three studies (Aimetti et al., 2019; Riben-Grundstrom et al., 2015; Sánchez-Martos et al., 2020) and BoP severity in one (Wohlfahrt et al., 2019). Implant-level mean values of PPD were reported in three trials (Aimetti et al., 2019; Sánchez-Martos et al., 2020; Wohlfahrt et al., 2019). One trial reported BoP severity and mean PPD values at patient level, but they were considered as an acceptable proxy of implant-level results and therefore further considered for the present systematic review (Ji et al., 2014). Finally, soft tissue level was reported in three trials (Aimetti et al., 2019; Riben-Grundstrom et al., 2015; Sánchez-Martos et al., 2020), and one trial reported also on bone loss and intra-operative morbidity (Wohlfahrt et al., 2019).

No studies reported results on peri-implantitis onset, need for further treatment, adverse events, post-operative morbidity, quality of life, economical costs, or treatment duration.

3.2.4 | Risk of bias

The risk of bias assessment of the included studies in relation to the three outcomes considered as most important is depicted in Figure 2.

With regard to treatment success, one trial was considered with some concerns (Aimetti et al., 2019), while the other was at high risk of bias (Wohlfahrt et al., 2019).

For BoP extent, two RCTs were considered with some concerns (Aimetti et al., 2019; Riben-Grundstrom et al., 2015), while the remaining one was at high risk of bias (Sánchez-Martos et al., 2020).

In relation to BoP severity, one trial was considered with some concerns (Ji et al., 2014) and the remaining one was at high risk (Wohlfahrt et al., 2019).

3.3 | Longitudinal changes

Results from individual studies on implant- and patient-level outcomes are reported in Tables S4 and S5, respectively.

Treatment success rates ranged from 30.9% (ultrasonics, curettes and sham laser) to 34.5% (ultrasonics, curettes and adjunctive laser) at 3 months (Aimetti et al., 2019) and from 8.3% (chitosan rotating brush) to 16.7% (titanium curettes) at 6 months (Wohlfahrt et al., 2019).

Reduction in BoP extent at 3 months was 19.4% (ultrasonics, curettes and sham laser) to 28.6% (ultrasonics) (Aimetti et al., 2019; Riben-Grundstrom et al., 2015), 27.2% (air-polishing) to 30.5% (ultrasonics) at 6 months (Riben-Grundstrom et al., 2015), 25.4% (air-polishing) to 41.8% (ultrasonics) at 9 months (Riben-Grundstrom et al., 2015) and 31.8% (air-polishing) to 35.1% (ultrasonics) at 12 months (Riben-Grundstrom et al., 2015). Reduction in BoP extent expressed as number of bleeding sites was 0.61 (ultrasonics, curettes and sham laser) to 0.92 (ultrasonics, curettes and adjunctive laser) at 3 months (Sánchez-Martos et al., 2020).

Reduction in BoP severity, expressed in a scale 0–3, was 0.3 (ultrasonics and air-polishing) to 0.5 (ultrasonics) at 3 months (Ji et al., 2014) and 0.61 (titanium curettes) to 0.84 (chitosan rotating brush) at 6 months (Wohlfahrt et al., 2019).

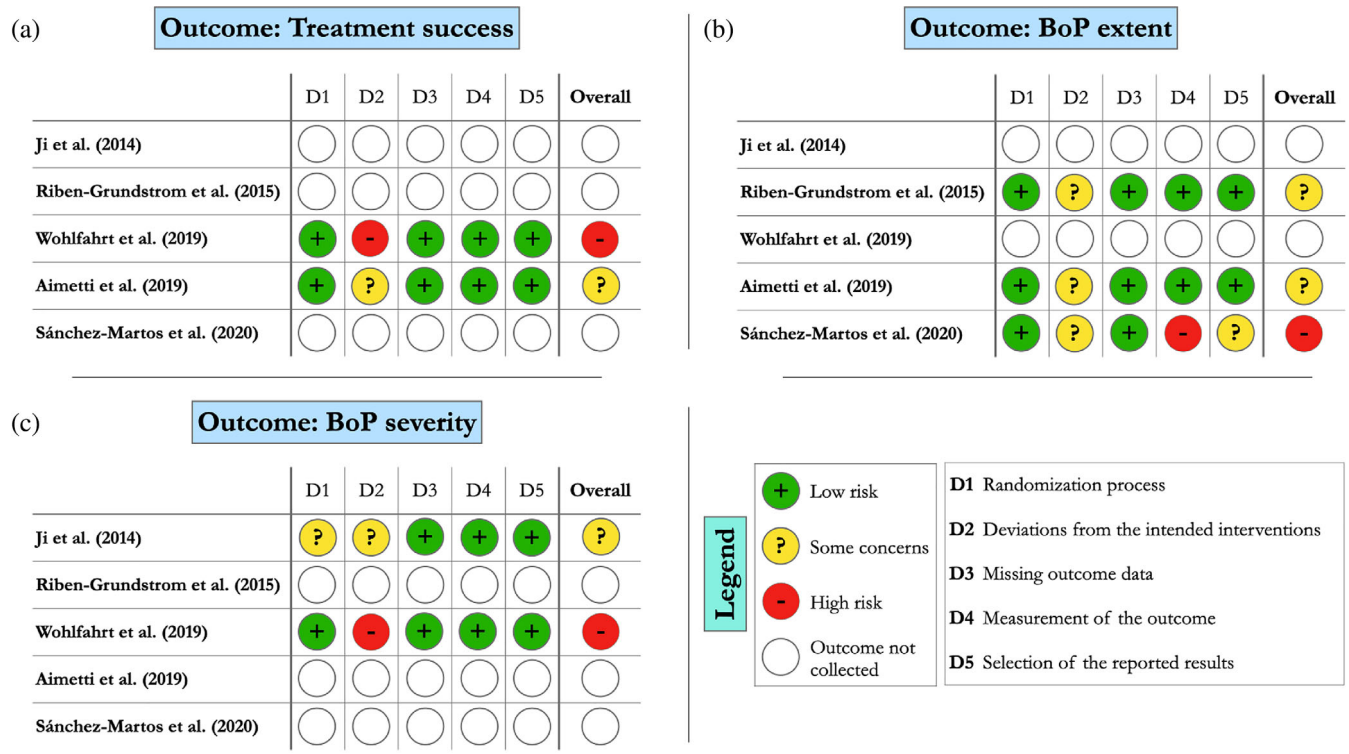

FIGURE 2 Risk of bias summary of the included studies: review authors' judgements in relation to the three outcomes considered critical or important: (a) treatment success; (b) bleeding on probing (BoP) extent; (c) BoP severity. D, domain

PPD reduction at 3 months was 0.1–0.6 mm (Aimetti et al., 2019; Ji et al., 2014; Sánchez-Martos et al., 2020) and 0.2–0.3 mm at 6 months (Wohlfahrt et al., 2019).

Mucosal recession ≥1 mm was detected on 5.5%–21.6% of the treated implants (Aimetti et al., 2019; Riben-Grundstrom et al., 2015), while the mean implant values of soft tissue level remained similar at 3 months in the trial from Sánchez-Martos et al. (2020).

No implants experienced bone loss at 6 months (Wohlfahrt et al., 2019); intra-operative pain measured on a visual analogue scale (VAS) (0–10 cm) without local anaesthesia was 3.5–4.6 (Wohlfahrt et al., 2019).

3.4 | Q1: Mechanical/physical therapy versus OHI alone

No RCT was identified to answer Q1.

3.5 | Q2: Best mechanical/physical therapy alone

Q2 was addressed by two studies (Riben-Grundstrom et al., 2015; Wohlfahrt et al., 2019). No statistically significant differences were recorded for any of the considered parameters when comparing glycine powder air-polishing instrumentation with ultrasonic (plastic coated tip) (Riben-Grundstrom et al., 2015) and chitosan rotating brush with titanium curettes (Wohlfahrt et al., 2019).

Because of the inherent differences in the interventions and comparisons provided, inter-group meta-analyses were not possible.

3.6 | Q3: Combinations versus mechanical/physical therapies alone

Q3 was addressed by three studies (Aimetti et al., 2019; Ji et al., 2014; Sánchez-Martos et al., 2020).

Ji et al. (2014) found no added effect of glycine powder air-polishing over the use of ultrasonic for any of the considered outcomes.

Aimetti et al. (2019) and Sánchez-Martos et al. (2020) addressed the added effect of laser over combinations of mechanical therapies (ultrasonics/curettes), which were considered together as a single mode of therapy. While Aimetti et al. (2019) found no added effect of the diode laser (980 nm) for any of the considered outcomes, Sánchez-Martos et al. (2020) reported a slightly higher reduction in BoP extent (number of sites with BoP) with the use of a diode laser (810 nm) (0.93 vs. 0.61).

Again, because of the inherent differences in the interventions and comparisons provided, inter-group meta-analyses were not possible.

3.7 | Q4: Repeated mechanical/physical therapy versus single administration

No RCT was identified to answer Q4.

4 | DISCUSSION

The present systematic review found no evidence for the efficacy of mechanical/physical instrumentation over OHI alone. Scarce evidence coming from single trials was found on comparison among different single modes/combinations of mechanical/physical therapies, mostly indicating no differences between the studied protocols. No evidence coming from RCTs is available to assess the possible benefits of repeating mechanical/physical instrumentation over a single administration. Collectively, the findings from this systematic review highlight a surprising paucity of RCTs that test mechanical/physical therapies of peri-implant mucositis.

One of the included trials provided OHI before any baseline assessment was made (Wohlfahrt et al., 2019). Therefore, in the absence of direct RCTs, it may open speculations on the efficacy of mechanical therapies (titanium curettes/chitosan brush) over no instrumentation. While a reduction of BoP severity was observed in both groups (0.61–0.84), treatment success occurred only in 12.5% of the studied implants. These results indirectly suggest how mechanical instrumentation may achieve peri-implant mucositis resolution only in a minority of the cases, at least when the current clinical parameters and thresholds are used as measures of treatment effect. The lower rates observed in the included studies after mechanical treatment of natural peri-implant mucositis cases compared to the ones reported for 'experimental mucositis' in humans (Chan et al., 2019) may also be open to speculations about the validity of that experimental model.

While the few trials comparing different single modes of mechanical/physical instrumentation and the added effect of glycine powder air-polishing over ultrasonics reported no differences between groups (Ji et al., 2014; Riben-Grundstrom et al., 2015; Wohlfahrt et al., 2019), one of the included trials reported a slight and non-clinically relevant added effect of the diode laser in reducing BoP extent over the use of mechanical instrumentation alone (Sánchez-Martos et al., 2020). However, the same trial was considered at high risk of bias in relation to the BoP extent, and a larger included trial testing diode laser reported no added effect over mechanical treatment alone on the same outcome (Aimetti et al., 2019).

Despite the non-availability of direct RCTs, one of the included trials reported results at multiple time points after providing repeated mechanical instrumentation (Riben-Grundstrom et al., 2015). While the first instrumentation session led to a longitudinal reduction of 20.9%–28.6% in BoP extent, a second and a third session resulted only in further slight reductions (1.9%–6.3% and 0%–11.3%, respectively). Since also OHI were repeated, it may be speculated that the effect of repeated mechanical instrumentation in improving clinical outcomes could be minimal, if any. However, repeated mechanical instrumentation may be potentially helpful to maintain the initial results, and this concept needs to be verified in future RCTs.

This systematic review defined treatment success, BoP extent and BoP severity, and proposed their implant-level assessment as the most important outcomes to be evaluated when studying the short-term efficacy of non-surgical treatments of peri-implant mucositis. Both the absence of BoP (i.e., treatment success) and the number of bleeding sites (i.e., BoP extent) have indeed been shown previously to be predictors of peri-implant bone loss (Berglundh et al., 2021; Berglundh, Wennström, & Lindhe, 2018; Karlsson et al., 2019). Conversely, while the use of indices to measure BoP severity has been proposed (Mombelli et al., 1987; Renvert et al., 2018), their value in predicting the risk of bone loss is yet to be determined.

The concepts presented in this systematic review should be interpreted only in the context of mechanical/physical professionally administered therapy of peri-implant mucositis. Any evaluation of patient-performed/prescribed interventions and of professionally administered non-mechanical/physical adjunctive measures was indeed beyond the scope of the present review. Similarly, the present results are not applicable to the prevention of peri-implant mucositis onset or recurrence (e.g., supportive peri-implant care). Furthermore, the potential damage to the implant surface inflicted by the different mechanical/physical treatment devices was outside the aims of this review, although it may potentially be of relevance in the long term. Despite the extensive literature search, only five RCTs fulfilling the inclusion criteria were found, resulting in scarce evidence exclusively coming from single trials, which prevented any data synthesis through meta-analyses and compromises the external validity of the findings. None of the included trials was considered at overall low risk of bias. Relevant short-term outcomes (e.g., treatment success, BoP extent, BoP severity) were sparsely reported, and even when analysed, they were often underpowered. Finally, the limited follow-up length prevented the analysis of relevant long-term outcomes (e.g., peri-implantitis onset).

5 | CONCLUSIONS

Several mechanical/physical instrumentation procedures including curettes, ultrasonics, lasers, rotating brushes and air-polishing are documented, but a beneficial effect over OHI alone or superiority over other procedures could not be demonstrated. Moreover, it remains unclear whether combinations of different procedures or their repetition over time might provide additional benefits.

5.1 | Implications for practice

Owing to the risk of progression into peri-implantitis, clinicians are strongly recommended to diagnose and treat peri-implant mucositis. No mechanical/physical instrumentation treatment protocol can, however, be considered as superior to others. Clinicians should be aware that resolution of peri-implant mucositis, or at least a reduction in its

extent and/or severity, may occur after non-surgical therapy, but still is unpredictable when the current clinical parameters are used as measures of treatment effect. Therefore, they should consider the prevention of peri-implant mucositis a key strategy to avoid peri-implant diseases.

5.2 | Implications for research

Definitive RCTs are needed that study the superiority of mechanical/physical instrumentation over OHI alone, any single mode of mechanical/physical instrumentation over others, combinations of mechanical/physical instrumentation over single modes and repetitions of mechanical/physical instrumentation over single administration.

When designing those trials, researchers are recommended to ensure adequate power targeting treatment success rate (i.e., BoP) as primary outcome for sample size calculations. Researchers are also encouraged to report additional outcomes of interest, including implant-level changes in BoP extent, BoP severity, PPD, soft tissue level, bone levels, as well as patient-level results on PROMs, costs, treatment duration and adverse events. Long-term reports are also needed to properly document disease recurrence and peri-implantitis onset. Special care is suggested on applying specific data analysis procedures for clustered and/or cross-over trials (e.g., mixed models) and on proper manuscript reporting through the CONSORT guidelines.

AUTHOR CONTRIBUTIONS

Anders Verket, Odd Carsten Koldsland, Dagmar Bunæs, Stein Atle Lie, and Mario Romandini contributed to study design, data acquisition, analysis and interpretation and manuscript drafting. All the authors gave their final approval of the version to be published.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest related to this study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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