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Efficacy of mechanical/physical approaches for implant surface decontamination in nonsurgical submarginal instrumentation of peri-implantitis. A systematic review.

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Author contributions

R.C., A.R., G.E.S. collected, analyzed the data and led to the writing; K.J., S.J., collected, analyzed the data and critically revised the manuscript; A.S., critically revised the manuscript.

Data availability statement

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

Abstract

Aim:

To evaluate the efficacy of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination, compared to non-surgical submarginal instrumentation alone/with placebo decontamination, in patients with peri-implantitis.

Materials and Methods:

Three focused questions were addressed and a systematic search for randomized controlled clinical trials (RCTs), controlled clinical trials and prospective cohort studies with definitions of peri-implantitis and a minimal follow-up of 6 months was conducted. The main outcome variables were reduction in pocket probing depth (PD) and bleeding on probing (BOP). Suppuration on probing, marginal peri-implant bone level changes, patient related outcomes and adverse events, implant survival, treatment success and disease resolution were assessed as secondary outcomes.

Results:

Out of 2398 findings, full-text articles were assessed for eligibility and nine (n=9 RCTs) were included in the present review. Five studies evaluated the effects of various laser types and in four studies efficacy of air-abrasive mechanisms and of a novel ultrasonic device was determined. At 6 months, PD reductions were observed in 9 studies but only Er,Cr:YSGG laser showed statistically significant higher reductions compared to the control group. BOP was statistically significantly reduced at 6 months in 2 studies following application of Er:YAG laser compared to controls. One study reported statistically significant reduction in BOP following application of air-polishing device as compared to control treatment. No statistically significant differences between treatment groups were reported for the secondary outcome variables. Due to the large heterogeneity of study designs, no meta-analysis was performed.

Conclusion:

Available evidence on efficacy of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination is limited by a low number of controlled studies and a high heterogeneity of study protocols. Clinical and patient-reported benefits remain to be demonstrated.

Clinical Relevance

Scientific rationale for the study

In patients with peri-implantitis, the efficacy of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination with/without additional measures, compared to non-surgical submarginal instrumentation alone/with placebo decontamination or to no treatment/supramarginal decontamination has not been sufficiently evaluated in order to give clinical recommendations.

Principal findings

Limited evidence on the efficacy of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination with/without additional measures showed at 6 months no statistically significant probing depth reductions compared to control groups, excepting the Er, Cr:YSGG laser. A few studies with adjunctive laser treatment and one with air-polishing showed statistically significant reductions in bleeding on probing compared to controls.

Practical implications

Based on the limited evidence, clinical and patient-reported benefits of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination with/without additional measures remain to be demonstrated.

Introduction

Dental implants have become nowadays a standard treatment procedure in the partially or fully edentulous dentition. Despite high survival rates, a remarkable and varying percentage (1%-45%) (Cosgarea, Sculean, Shibli, & Salvi, 2019; Derks & Tomasi, 2015; A. Roccuzzo, Imber, J-C, Marruganti, C, Salvi, GE, Ramieri, G, Roccuzzo, M, 2022; Salvi, Cosgarea, & Sculean, 2017) of biological complications has been reported. Peri-implantitis describes a plaque-associated pathological condition at implant-supporting tissues with signs of inflammation in the peri-implant mucosa and loss of the supporting bone (T. Berglundh et al., 2018b; Salvi et al., 2017). The lack of an unanimous definition for peri-implant diseases, debated at the last consensus report of the 2017 World Workshop of the Classification of periodontal and peri-implant diseases where clear case definitions and clinical considerations for the correct diagnosis of peri-implant diseases were established (T. Berglundh et al., 2018b).

Considering the complex histopathological characteristics of the peri-implantitis lesion and the unpredictable, accelerating pattern of disease progression (T. Berglundh, Jepsen, Stadlinger, & Terheyden, 2019; Derks et al., 2016), treatment of peri-implantitis represents a challenge for every clinician. The main treatment goals are resolution of inflammation and arrest of further peri-implant bone loss. Translated into clinical terms, this can be diagnosed in pocket probing depth reduction and absence of bleeding on probing and/or suppuration (BOP) (T. Berglundh et al., 2019). Providing optimal access to contaminated implant surfaces and effective biofilm removal from these, are mandatory steps for achieving the treatment goal. So far, no consensus for the most effective treatment of peri-implantitis has been established. Hence, non-surgical treatment of peri-implantitis represents the first step in disease resolution and aims at an effective removal of the biofilm (A. Roccuzzo, De Ry, S.P., Sculean, A., Roccuzzo, M., Salvi, G.E., 2020).

Various mechanical/physical approaches for submarginal instrumentation (i.e. air-powder abrasive systems, ultrasonic devices, Er:YAG laser, chitosan brushes) have been evaluated for the non-surgical management of peri-implantitis. A recent meta-analysis emphasized that alternative measures for biofilm removal lead to statistically significant superior results towards BOP reduction compared to mechanical debridement alone (Ramanauskaite, Fretwurst, & Schwarz, 2021). The lack of sufficient long-term data and the variability in study designs and investigated methods lead to inconclusive results indicating so far only limited efficacy of non-surgical submarginal therapy of peri-implantitis (Joshi, Gaikwad, Padhye, & Nadgere, 2022; Ramanauskaite et al., 2021).

Therefore, the aim of this systematic review was to answer the following PICOS questions: in patients with peri-implantitis what is the efficacy of i) non-surgical submarginal instrumentation with mechanical and/or physical decontamination methods (e.g. air-polishing, sonic/ultrasonic devices, brushes, lasers, alone or in combination) ii) non-surgical submarginal instrumentation

with mechanical and/or physical decontamination methods (e.g. air-polishing, sonic/ultrasonic devices, brushes, lasers, alone or in combination) including additional measures (e.g. chlorhexidine irrigation) compared to non-surgical submarginal instrumentation alone/with placebo decontamination with/without additional measures and iii) non-surgical submarginal instrumentation with/without placebo decontamination, non-aiming at mechanical decontamination (e.g., scalers/curettes) compared to no treatment/supramarginal instrumentation in terms of probing depth (PD) and bleeding on probing (BOP) reduction, in randomized controlled clinical trials (RCTs) with at least 6 months follow-up. Secondarily, suppuration on peri-implant probing (SOP), change in marginal bone levels (MBL), patient-reported outcome measures (PROMs), implant survival (IS), treatment success (TS) and resolution of peri-implantitis (RP) were also determined.

2. Material and methods

2.1 Study registration and reporting format

A detailed protocol according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was designed (Page et al., 2021), critically reviewed and approved by all authors and registered to the PROSPERO database (CRD42022333946, https://www.crd.york.ac.uk/prospero/#searchadvanced).

2.2 Focused questions

The following questions were set using the PICOS criteria (Stone, 2002):

PICOS 1:

- In patients with peri-implantitis, what is the efficacy of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination methods (e.g. air-polishing, sonic/ultrasonic devices, lasers) alone or combinations thereof, compared to non-surgical submarginal instrumentation with placebo decontamination (non-aiming at mechanical/physical decontamination, e.g., scalers to remove hard deposits with adjunctive saline irrigation), in terms of change in peri-implant PD and/or change in BOP, in parallel-arm and split-mouth RCTs with ≥ 10 recruited/randomized subjects per treatment arm, in controlled clinical trials and prospective cohort-studies with ≥ 30 recruited subjects with ≥ 6 months duration?

PICOS 2

- In patients with peri-implantitis, what is the efficacy of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination methods (e.g. air-polishing, sonic/ultrasonic devices, lasers) alone or combinations thereof and additional measures/interventions (e.g. irrigation with antiseptics), compared to non-surgical submarginal instrumentation with placebo decontamination (non-aiming at

mechanical/physical decontamination, e.g., scalers to remove hard deposits with adjunctive saline irrigation) and additional measures/interventions (e.g. irrigation with antiseptics), in terms of change in peri-implant PD and/or change in BOP, in parallel-arm and split-mouth RCTs with ≥ 10 recruited/randomized subjects per treatment arm, in controlled clinical trials and prospective cohort-studies with ≥ 30 recruited subjects with ≥ 6 months duration?

PICOS 3

- In patients with peri-implantitis, what is the efficacy of non-surgical submarginal instrumentation with placebo decontamination (non-aiming at mechanical/physical decontamination, e.g., scalers to remove hard deposits with adjunctive saline irrigation) compared to no treatment or supramarginal mechanical cleaning in terms of change in peri-implant PD and/or change in BOP, in parallel-arm and split-mouth RCTs with ≥ 10 recruited/randomized subjects per treatment arm, in controlled clinical trials and prospective cohort-studies with ≥ 30 recruited subjects with ≥ 6 months duration?

2.3 Eligibility

2.3.1 (P) population, (I) Intervention, (C) Comparison, (O) Outcome, (S) Study design

Population (P): patients with peri-implantitis;

Intervention (I):

I1: non-surgical submarginal instrumentation with mechanical and/or physical decontamination methods (e.g. air-polishing, sonic/ultrasonic devices, brushes, lasers, alone or in combination);

I2: non-surgical submarginal instrumentation with mechanical and/or physical decontamination methods (e.g. air-polishing, sonic/ultrasonic devices, brushes, lasers, alone or in combination) including additional measures (e.g. chlorhexidine irrigation);

I3: non-surgical submarginal instrumentation with/without placebo decontamination, non-aiming at mechanical decontamination (e.g., scalers/curettes).

Comparison (C):

C1: non-surgical submarginal instrumentation with/without placebo decontamination, non-aiming at mechanical decontamination (e.g., scalers/curettes);

C2: non-surgical submarginal instrumentation with placebo decontamination, non-aiming at mechanical decontamination (e.g., scalers/curettes) including additional measures (e.g. chlorhexidine irrigation);

C3: no treatment/supramarginal mechanical cleaning

Outcome (O):

Primary outcome:

PD reduction, BOP reduction

Secondary outcomes:

Change in suppuration/ SOP, change in MBL, PROMs, IS, TS, RP;

Antimicrobial photodynamic therapy was not within the scope of this review.

Study design (S):

The following study designs were considered: parallel-arm and split-mouth RCTs with minimum 10 subjects per treatment arm, controlled clinical trials and prospective cohort-studies with minimal 30 subjects of at least 6-month duration.

2.3.2 Inclusion criteria:

- Clinical studies in partially and in fully-edentulous systemically healthy subjects;
- Studies reporting on titanium and zirconia implants;
- Subjects with peri-implantitis (≥1 implant);
- Studies with a clear definition of peri-implantitis;
- Studies reporting treatment in ≥ 10 recruited/randomized patients in each treatment arm diagnosed with peri-implantitis; observational studies with ≥ 30 recruited patients;
- If data were not presented separately or detailed enough, authors were contacted to gain information;
- Studies reporting non-surgical submarginal mechanical and/or supramucosal peri-implant instrumentation/cleaning;
- minimum observation period of 6 months for the following outcome parameters: PD-reduction, change in BOP, suppuration/SOP, change in MBL, PROMs, IS, TS, RP; adverse events;
- Timepoint of publication: up to April 30th, 2022

2.3.3 Exclusion criteria:

- Studies reporting on subperiosteal, zygomatic, blade, hollow-cylinder, hollow-screw implants;
- Studies not reporting on treatment modalities for non-surgical submarginal mechanical peri-implant instrumentation;
- Studies reporting on treatment of peri-implant mucositis;
- Studies reporting on surgical treatment of peri-implantitis;
- Lack of reporting of the two primary outcomes (e.g. changes in BOP and peri-implant PD)
- No data on peri-implant therapeutic intervention;

2.4 Search strategy, validity and quality assessment

Literature search was performed on electronic databases, including PubMed (https://nobility.nem.nih.gov/pubmed), Ovid/EMBASE (https://ovidsp.dc2.ovid.com), and Cochrane database (https://www.cochranelibrary.com/web/cochrane/advanced-search/search-manager) for randomized controlled clinical trials (RCTs), controlled clinical trials, prospective cohort-studies, reporting results up to April 30th, 2022. Only articles published in English were considered and no manual search was conducted.

The following search terms were applied: “peri-implantitis“ [MeSH Term] OR “periimplantitis“ AND “instrumentation” [MeSH Term] OR “submarginal peri-implant instrumentation” OR “submarginal peri implant instrumentation” OR “submarginal instrumentation” “submucosal instrumentation” OR “debridement” [MeSH Term] OR “mechanical debridement“ OR “peri-implant debridement” OR “submucosal debridement” OR “non-surgical peri-implantitis therapy“ OR “treatment“ [MeSH Term] OR “non-surgical treatment” OR “nonsurgical treatment” OR “therapy” [MeSH Term] OR “non-surgical therapy” OR “nonsurgical therapy” OR “non surgical therapy” OR “submucosal instrumentation“ OR “therapy, soft tissue” [MeSH Term] OR “submarginal instrumentation” OR “submarginal cleaning” OR “submucosal cleaning” OR “antiseptic treatment”.

Validity assessment

Titles, abstracts, and summaries were independently screened by two reviewers (R.C. and A.R.) for potential full text screening. Inter-reviewer agreement was evaluated and computed using kappa statistics (Landis & Koch, 1977). Full text screening, methodological quality assessment, and data extraction was conducted by three independent reviewers (A.R., K.J. and R.C.). In case of disagreement, resolution was brought to discussion among the three reviewers as well as additional reviewers (A.S., S.J., G.E.S.).

Quality assessment of the included studies

For all included studies, quality assessment was performed (R.C. and A.R.) according to adopted items of the ROBINS-I tool for assessing the quality of non-randomized studies (J. A. Sterne et al., 2016) and the RoB 2 tool for assessing risk of bias for randomized clinical trials (J. A. C. Sterne et al., 2019).

2.5 Primary and secondary outcomes

The primary outcome variables included the change in peri-implant PD and in peri-implant BOP at implants with peri-implantitis subjected to non-surgical peri-implant therapy (i.e. submarginal mechanical/physical instrumentation).

As secondary outcomes the following parameters were included:

- Change in suppuration or SOP

- Change in peri-implant MBL
- PROMs and adverse events
- IS
- TS
- RP

2.6 Data analysis

Means, standard deviations, 95% confidence intervals were extracted and summarized in Table 1. Results reporting PROMs or specific non-quantifiable outcomes were also documented. Due to the heterogeneity of the included studies (i.e. study design, treatment methods and frequency, outcome measures, inclusion/exclusion criteria, peri-implantitis definition) no quantitative data analysis including a minimum of three studies with comparable designs providing reliable data for clinical recommendations was performed. Consequently, no meta-analyses were performed.

Results

3.1 Search

A total of 2398 titles were identified through the electronic search and 358 remained for abstract screening. One record from the manual or grey literature search could be found (Figure 1). 1949 records were excluded following abstract reading and 27 after full-text analysis. Nine studies were included in the present review. Based on title and abstract screening, inter-examiner agreement was calculated (Cohen's Kappa score 0.84). Included studies and their characteristics and results are presented in Tables 1 and 2. Excluded studies and reasons for exclusion are displayed in Table 3.

3.2 Laser therapy

3.2.1 Study design

Five out of ten studies included in the present review investigated the efficacy of various types of laser therapy (i.e. Nd:YAG, diode laser, Er, Cr: YSGG, Er:YAG) (Table 1) (Abduljabbar, Javed, Kellesarian, Vohra, & Romanos, 2017; Alpaslan Yayli et al., 2022; A. Roccuzzo et al., 2022; Schwarz, Bieling, Bonsmann, Latz, & Becker, 2006; Schwarz et al., 2005). All five studies were RCTs, single- or double-blinded, had a parallel design and were conducted at university settings. Funding was reported in three studies (Alpaslan Yayli et al., 2022; A. Roccuzzo et al., 2022; Schwarz et al., 2006). All included studies compared the laser intervention to a control group where treatment had been performed with hand curettes with/without chlorhexidine digluconate irrigation. Another study included two laser test groups:

diode laser and Er,Cr:YSGG (Alpaslan Yayli et al., 2022). Further details regarding study settings, duration and target population are described in Table 1.

3.2.2 Definition of peri-implantitis

Disease definition was reported in all studies based on the parameters PD, BOP, SOP and peri-implant bone loss (Table 1). Three studies considered PD ≥ 4 mm (Abduljabbar et al., 2017; Schwarz et al., 2006; Schwarz et al., 2005), one study PD 4-6 mm (Alpaslan Yayli et al., 2022), one study PD≥ 5 mm (A. Roccuzzo et al., 2022) and one study an additional group of severe peri-implantitis with PD≥ 7 mm (Schwarz et al., 2006). Peri-implant bone-loss was reported in four studies starting with 2-3 mm bone loss (Abduljabbar et al., 2017; Alpaslan Yayli et al., 2022; A. Roccuzzo et al., 2022; Schwarz et al., 2005). One study included moderate and advanced bone loss (Schwarz et al., 2006).

3.2.3 Study samples

The number of patients treated in the included studies ranged from 20 (10 subjects/ group) to 63 (31-32 subjects/ group) and their mean age ranged from 40.5 years to 68.5 years. Three studies reported on the smoking status, two of which included nonsmokers (Alpaslan Yayli et al., 2022; Schwarz et al., 2006), while the third one included 5 (out of 25 subjects) smokers (A. Roccuzzo et al., 2022). Only one study reported on the periodontal status of the treated subjects who all had a history of treated periodontitis and were successfully attending a supportive periodontal care (SPC) program (A. Roccuzzo et al., 2022). Only two studies study reported the exact type of the prosthetic reconstruction (Alpaslan Yayli et al., 2022). Further details related to implant characteristics are shown in Table 1.

3.2.4 Study interventions

The interventions varied with respect to the laser type and protocol, as well as the pre- and post-intervention protocol (Table 1). One study used Nd:YAG laser (Abduljabbar et al., 2017), with no clear specification related to pre- and post-treatment oral hygiene protocol. Er:YAG laser was used in two studies (Schwarz et al., 2006; Schwarz et al., 2005) and in a further study another type of Er:YAG laser (Er,Cr:YSGG) (Alpaslan Yayli et al., 2022). Two studies used diode laser (Alpaslan Yayli et al., 2022; A. Roccuzzo et al., 2022), however with different application frequency (i.e. 1x and 3x) and wave length (i.e. 810 nm vs. 940 nm).

The control interventions consisted in mechanical debridement with plastic curettes in three studies (Abduljabar et al., 2017; Schwarz et al., 2005; 2006) or with titanium curettes in two studies (Alpaslan Yayli et al., 2022; Roccuzzo et al., 2022). In two studies of the same author there was additional submarginal irrigation with chlorhexidine digluconate solution 0.2% and

gel application (1%) (Schwarz et al., 2005; 2006). In a further study, there was a submarginal rinsing with sterile saline solution and sham laser treatment (Roccuzzo et al., 2022).
Pre-treatment oral hygiene instructions were delivered in four studies (Alpaslan Yayli et al., 2022; A. Roccuzzo et al., 2022; Schwarz et al., 2006; Schwarz et al., 2005), while in two studies also supragingival professional implant/tooth-cleaning and polishing was performed (Schwarz et al., 2006; Schwarz et al., 2005). After the study interventions, oral hygiene instructions were delivered only in two studies (Schwarz et al., 2006; Schwarz et al., 2005). Schwarz et al. 2005, 2006 performed also supragingival professional implant/tooth cleaning at all follow-up timepoints (Schwarz et al., 2006; Schwarz et al., 2005). In all studies treatments were conducted by trained dentists without removal of the suprastructure. In five studies all interventions were performed under local anesthesia (Renvert, Lindahl, Roos Jansaker, & Persson, 2011; A. Roccuzzo et al., 2022; Schwarz et al., 2006; Schwarz et al., 2005).

3.2.5 Outcomes

Primary outcome

Peri-implant probing depth (PD)

All included studies showed reductions at 3m and/or 6m. One study showed statistically significant higher PD reductions at 3 months for Nd:YAG laser as compared to plastic curettes (Abduljabbar et al., 2017) but without any statistically significant inter-group differences at 6 months. A further study reported at 6 months statistically significant higher PD reductions for the Er,Cr:YSGG treatment compared to both the control as well as the diode laser (Alpaslan Yayli et al., 2022). The other included studies showed no statistically significant intergroup differences. Mean PD reduction ranged in the laser intervention group from 0.8 mm to 1.5 mm at 6 m.

Bleeding on probing (BOP)

All studies reported BOP reductions at 6 m ranging between 11% and 48%. However, in two of the five included studies investigating laser treatment no statistically significant differences were obtained compared to the control treatment (Alpaslan Yayli et al., 2022; A. Roccuzzo et al., 2022). Two studies reported statistically significantly higher BOP reductions at 6 months for the Er:YAG laser therapy as compared to the control mechanical instrumentation with curettes (Schwarz et al., 2006; Schwarz et al., 2005). A further study showed statistically significant higher PD reductions at 3 months for Nd:YAG laser as compared to plastic curettes (Abduljabbar et al., 2017) but without any statistically significant inter-group differences at 6 months.

Secondary outcomes

Suppuration on probing (SOP)

SOP was reported in three out of the five studies and was reduced in all studies at 6 m as compared to baseline (Table 1) (A. Roccuzzo et al., 2022; Schwarz et al., 2006; Schwarz et al., 2005). Nonetheless, no statistically significant differences between the treatment groups were observed in any of the studies.

Peri-implant marginal bone level (MBL)

Peri-implant bone level changes 6 months following treatment were reported in two studies (Table 1) (Abduljabbar et al., 2017; A. Roccuzzo et al., 2022). Mean bone level changes ranging from 0.004 mm (A. Roccuzzo et al., 2022) to 0.1 mm (Abduljabbar et al., 2017) were reported. No statistically significant changes were registered between the treatment groups.

Patient-reported outcome measures (PROMs) and adverse events

None of the included studies reported on patient related outcomes. Adverse events such as suppuration or discontinuation from the study due to persisting/exacerbation of the peri-implant infection were reported in two studies (3 patients with each 2 implants) (Schwarz et al., 2006; Schwarz et al., 2005).

Implant survival (IS), Treatment success (TS), Resolution of peri-implantitis (RP)

None of the studies reported on implant survival or resolution of peri-implantitis. TS was reported only in one study in patients treated with laser (41.7%) and in 6 patients within the control group (46.2%) (Roccuzzo et al., 2022).

3.3 Ultrasonics/ air-abrasive systems therapy

3.3.1 Study design

Two out of nine studies investigated the efficacy of air-abrasive delivery (Merli et al., 2020; Sahm, Becker, Santel, & Schwarz, 2011) (Table 1 and 2) and one study of ultrasonics (Renvert et al., 2009) and a further study of a novel ultrasonic device (i.e. the Vector ® system) (Karring, Stavropoulos, Ellegaard, & Karring, 2005) (Table 2). All four studies were RCTs, single- or double-blinded. Two studies had a parallel design (Merli et al., 2020; Sahm et al., 2011) and one was a split-mouth pilot study (Karring et al. 2005). With the exception of one study (Merli et al., 2020) that was carried out in a private practice setting, the other three studies were conducted at university settings. Funding was reported in all four studies. One study compared air-abrasive to ultrasonics and considered also several test groups (Merli et al., 2020). The other three studies compared the test interventions to mechanical debridement with hand curettes with/without chlorhexidine digluconate irrigation (control group) (Karring et al., 2005;

Renvert, Samuelsson, Lindahl, & Persson, 2009; Sahm et al., 2011). Further details regarding study settings, duration and target population are described in Tables 1 and 2.

3.3.2 Definition of peri-implantitis

Definitions of peri-implantitis were reported in all studies based on the parameters PD, BOP, SOP and peri-implant bone loss (Table 1 and 2). Two studies included implants with PD ≥ 4 mm (Renvert et al., 2009; Sahm et al., 2011), one study max. PD 5-8 mm (Merli et al., 2020) and two studies PD≥ 5 mm (Karring et al., 2005; Renvert et al., 2009). Peri-implant bone-loss was mentioned in all studies starting at 1.5-3 mm (Karring et al., 2005) and in some studies limiting the bone loss at a maximal value of 2.5-5 mm (Merli et al., 2020; Renvert et al., 2009).

3.3.3 Study samples

The number of subjects ranged from 11 (11 subjects/ group) (Karring et al., 2005) to 64 (16 subjects/ group) (Merli et al., 2020) and their mean age ranged from 22 to 98 years. Three studies reported on smoking and included a limited number of smokers (i.e. 5 patients/25% of the patients) (Karring et al., 2005; Merli et al., 2020; Renvert et al., 2009). Three studies included patients with treated periodontitis and enrolled in SPC (Karring et al., 2005; Renvert et al., 2009; Sahm et al., 2011). Further details related to implant characteristics or prosthetic suprastructure and type of fixation are summarized in tables 1 and 2.

3.3.4 Study interventions

The interventions varied with respect to the used air-abrasive/ultrasonic systems and protocols, as well as the pre- and post-treatment protocol (Table 1 and 2). Two studies used air-abrasive decontamination (Merli et al., 2020; Sahm et al., 2011), two studies used in the test group a ultrasonic devices (Karring et al., 2005; Renvert et al., 2009). One study repeated the baseline treatment after 3 months (Karring et al., 2005).

Control interventions included submarginal debridement with ultrasonic scalers (Merli et al., 2020), with titanium curettes and polishing with rubber cups (Renvert et al., 2009), with carbon fiber curettes (Karring et al., 2005; Sahm et al., 2011).

In two studies special oral hygiene programs including supramucosal professional implant/tooth cleaning were delivered prior study intervention (Merli et al., 2020; Sahm et al., 2011). Post-treatment oral hygiene programs and professional cleanings were reported in fours studies (Karring et al., 2005; Renvert et al., 2009). One study applied directly after the study intervention chlorhexidine digluconate gel and rinsing in both test and control groups (Sahm et al., 2011), and another study prescribed for two weeks after treatment chlorhexidine digluconate rinsing (Merli et al., 2020). The therapy in all studies was conducted by trained dentists. In one study the interventions were performed after removal of the prosthetic

reconstructions (Merli et al., 2020). Local anesthesia before therapy was given in one studies (Renvert et al., 2009).

3.3.5 Outcomes

Primary outcome:

Peri-implant probing depth (PD)

AI included studies reported reductions at 3m and/or 6m, with no statistically significant differences between the treatment groups (Tables 1 and 2). Mean PD reductions were < 1.3 mm compared to baseline (range 0.1±0.9mm – 0.8±0.5 mm). The smallest PD reductions were observed with the Vector ® system.

Bleeding on probing (BOP)

All studies reported BOP reductions at 6 m with a range from 0.7% to 70%. One study reported a statistically significant higher BOP reduction following air-polishing delivery compared to the control group (Sahm et al., 2011). The other studies failed to show any statistically significant differences between the treatment groups.

Secondary outcomes

Suppuration on probing (SOP)

One study reported SOP as being reduced from 4±25% at baseline to 2±15% at 6 months in the air-polishing treatment group (Merli et al., 2020). The reductions were comparable to the control group. In the remaining two studies SOP was not reported (Karring et al., 2005; Renvert et al., 2009).

Peri-implant marginal bone level (MBL)

Peri- implant marginal bone level change was mentioned in two studies (Karring et al., 2005; Renvert et al., 2009) (Tables 1 and 2) with reported values of 0.3 mm (Karring et al., 2005). The second study reported the baseline peri-implant bone level and that after 6 m with none of the implants experiencing bone level changes ≥ 2.5 mm (Renvert et al., 2009).

Patient reported outcome measures (PROMs) and adverse events

PROMs as displayed by pain perception during and one week after treatment was reported only in one study (Merli et al., 2020). Higher pain values on a visual analogue scale (VAS) were recorded during treatment in the air polishing group (2.3±2.7) as compared to mechanical debridement with ultrasonic scalers (2.1±2.1). After one week, similar VAS pain values were displayed in both treatment groups (Table 2). VAS satisfaction provided at 6 months a higher value for the glycine powder group (7.5±3.0) as compared to the control group (6.9±2.6).

OHIP-14 reductions were reported also in only one study (Merli et al. 2020), indicating a higher reduction at 6 months in the air-abrasive group.

Most of the studies reported no occurrence of adverse events. One study reported a higher frequency of adverse events (e.g. swelling and bleeding) in the air-polishing group (n=4) as compared to the ultrasonic treatment group (n=1) (Merli et al., 2020).

Treatment success (TS), implant survival (IS), resolution of peri-implantitis (RP)

Implant survival and treatment success were defined and reported in two studies (Merli et al., 2020).

Thirteen % failures were reported by Merli et al., while treatment success as evaluated by composite success criteria was lower in the air-polishing group (14%) compared to the control group (37%) (Merli et al., 2020).

Resolution of peri-implantitis was not reported in any of the studies.

3.4 Quality assessment (risk of bias across studies)

The quality assessment of the ten included RCTs was performed according to the Risk of Bias 2.0 tool (J. A. C. Sterne et al., 2019), demonstrated a low risk of bias and its results are summarized in Table 4.

4. Discussion

In the present systematic review, outcomes from clinical studies published up to April 30th 2022 and reporting on the efficacy of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination in peri-implantitis lesions as compared to non-surgical submarginal instrumentation alone/with placebo were analyzed. From the nine included studies, five reported on the efficacy of various laser types and four on the effects of air-abrasive decontamination.

Following the recommendations of the 8th European Workshop on Periodontology published in 2012 (Sanz, Chapple, & Working Group 4 of the, 2012) and the highlighted diagnostic parameters for the diagnosis of peri-implantitis by the World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions (T. Berglundh et al., 2018a) and the fact that PD and BOP were recently shown to be of important predictive value for disease progression (J. Berglundh, Romandini, Derks, Sanz, & Berglundh, 2021; Carcuac, Derks, Abrahamsson, Wennstrom, & Berglundh, 2020), we selected PD and BOP as main outcome variables, and included only studies with the recommended follow-up of at least 6 months (Sanz et al., 2012) Consequently, all included studies provided at least 6 months outcomes of BOP and PD.

Considering that composite outcomes for disease resolution ("absence of deep probing depths with BOP and SOP") were also encouraged to be evaluated in clinical studies on the treatment of peri-implantitis (Jepsen et al., 2019; Sanz et al., 2012), we further analyzed MBL, SOP, IS, TS and RP. PROMs and adverse events, as recommended by the 8th European Workshop on Periodontology (Tonetti, Palmer, & Working Group 2 of the, 2012) were also evaluated. However, as previously (Derks et al., 2022), the majority of the studies did not report on PROMs and/or adverse events: more specifically, among the nine included studies, only one evaluated PROMs as depicted by pain perception and satisfaction on a VAS scale, and by an OHIP-14 questionnaire (Merli et al., 2020).

Efficacy of laser treatment

All studies evaluating the use of various types of lasers showed in both test and control groups PD and BOP reductions at 3, 6 and/or 12 months compared to baseline. Notably, only two studies using Nd:YAG (Abduljabbar et al., 2017) and Er:Cr:YSGG laser (Alpaslan Yayli et al., 2022) displayed statistically significant PD outcomes compared to mechanical debridement alone. However, only Nd:YAG laser seemed to provide only short-term (3 months) statistically significant differences between the treatment groups (Abduljabbar et al., 2017). On the other hand, the treatment with Er:Cr:YSGG laser showed higher PD reductions at 6 months, not only as compared to mechanical debridement, but also compared to the single administration of a diode laser (Alpaslan Yayily et al., 2022). None of the other included studies showed any statistically significant differences for PD between laser treatments and their respective mechanical debridement modalities (A. Roccuzzo et al., 2022; Schwarz et al., 2006; Schwarz et al., 2005). On the other hand, BOP was reduced in all included laser studies, with statistically significant differences between test and control treatments in only three studies (Abduljabbar et al., 2017; Schwarz et al., 2006; Schwarz et al., 2005). Similar to the PD results, treatment with Nd:YAG laser failed to maintain statistical significant differences at the 6 months evaluation.

These results are in line with those from another systematic review and meta-analysis reporting statistically significantly higher BOP reductions with the alternative measures for biofilm removal as compared to control groups (p=0.01, WMD -28.09%, 95% CI (-35.43; -20.76)), but no statistically significant differences for PD (p=0.19, WMD -0.27 mm, 95% CI (-0.68; 0.13)) (Ramanauskaite et al., 2021). Noteworthy to mention is the fact that in the aforementioned review, the authors pooled in the meta-analysis various alternative treatments including Er:YAG laser, ultrasonic devices and air-powder abrasive devices. In the present systematic review, ultrasonic devices were considered as a mechanical decontamination method used as a control treatment. Moreover, alternative treatments such as lasers or air-abrasive systems or ultrasonics provide very different decontamination approaches, heterogenous treatment

protocols and a large variety in the number of repeated therapies, and thus, the studies reporting on these treatments were not pooled for a quantitative analysis. In order to provide robust outcomes to be used for guideline recommendations, a minimum number of 3 studies with a comparable protocol should be included in a meta-analysis. Unfortunately, the current literature does not provide these studies with a minimum follow-up period of 6 months. We identified various adjunctive/single mechanical decontamination (i.e. various types of lasers including diode, Er:YAG with different wavelengths, settings and number of treatment sessions with or without additional measures such as CHX, air-abrasive systems or others like ultrasonics) and different treatment protocols. Based on the reasons mentioned above, the group decided to abstain from conducting meta-analyses with respect to the primary and secondary outcomes.

The presence of SOP, despite the evidence on its association between peri-implant bone loss, PD, and defect morphology in patients with peri-implantitis (Monje, Vera, Munoz-Sanz, Wang, & Nart, 2021), was reported only in two studies (Renvert et al., 2011; A. Roccuzzo et al., 2022) indicating a significant reduction at 3 and/or 6 months without any statistically significant differences between the treatment groups. Consequently, it seems that this parameter has been so far vastly under-reported.

Peri-implant MBL changes as reported in two studies (Abduljabbar et al., 2017; A. Roccuzzo et al., 2022) showed insignificant changes over 6 months, without statistically significant group differences. These findings corroborate those of the aforementioned meta-analysis (Ramanauskaite et al., 2021), where alternative decontamination methods showed no superiority over control groups (p=0.34, WMD -0.21 mm, 95% CI (-087; 0.46)).

Implant survival, treatment success and resolution of inflammation are parameters very seldom reported in studies. In this review, only one study on lasers reported on implant survival/treatment success (A. Roccuzzo et al., 2022), providing success rates ranging between 41-47%. No resolution of peri-implantitis was reported in any of the selected studies. One further study, compared treatment with Er:YAG laser (100 mj/pulse, 10 Hz, 12.7 j/cm2, cone-shaped sapphire tip) to air-abrasive decontamination with glycine powder using a subgingival nozzle (Renvert et al., 2011). The authors reported PPD reductions at 6m in both treatment groups of 0.9±0.8mm in the laser group and of 0.8±0.5mm in the air-abrasive group. BOP was not detected in 30.9% of the laser treated implants and 25% of the implants in the air-abrasive group. A reduction of SOP, improved conditions and treatment success (47% in laser group, 44% in air-abrasive group) were also observed in both groups. No statistically significant differences between the two treatments were reported (p>0.05). In this study suprastructures were removed before treatments and all treatments were performed by a dental hygienist. Due to methodological discrepancies, this study was not included in the

present review, however, its results are consistent with those reported in the herein included studies.

Efficacy of air-abrasive decontamination

All four studies evaluating air-abrasive decontamination in peri-implantitis lesions reported improvements in the PD values at follow-ups but no statistically significant differences between the treatment groups for PD reduction at 3 and/or 6 months. Moreover, despite higher BOP reductions in the test groups, three of these studies failed to show any statistically significant difference at 3/6 months (Merli et al., 2020; Karring et al., 2005; Renvert et al., 2009). Only one study (Sahm et al., 2011) reported statistically significantly higher BOP reductions at 6 months in the air-abrasive group as compared to carbon curettes and pocket irrigation with chlorhexidine digluconate (CHX) solution (0.1%) and subgingival CHX-gel application (1%). Corroborating these results, a systematic review and meta-analysis on the efficacy of air-polishing for the non-surgical treatment of periimplantitis showed no statistically significant additional PD-reduction with air-abrasive methods (p=0.149, WMD: -0.394mm, 95% CI (-0.92; 0.14)(Schwarz, Becker, & Renvert, 2015). On the other hand, based on the included study (Sahm et al., 2011), a statistically significantly higher BOP reduction at 6 months (p=0.048, WMD -23.83, 95% CI (-47.47; -0.20)) was observed. Noteworthy to mention, is the fact that one study compared carbon curettes vs. air-polishing (Sahm et al., 2011). In the present review, considering the non-neglectable protocol heterogeneity of these studies, and the limited evidence, no meta-analysis was performed for any of the investigated parameters.

Similar effects were observed for SOP reduction, that was reported in one study (Merli et al., 2020) showing an improvement at 3/6 months compared to baseline, but without statistically significant group differences. Peri-implant bone level changes were reported in four of the five studies reporting on air-abrasive decontamination and no statistically significant additional effect was observed for the investigated treatment method.

Despite the fact that peri-implant decontamination with air-abrasive systems was not associated with any adverse events (i.e. emphysema), in the one study evaluating PROMs (Merli et al., 2020), more pain was reported with the air-abrasive method as compared to submarginal debridement with ultrasonic scalers but without statistically significance. Interestingly, in this study more failures and less treatment success as defined by composite success criteria (Heitz-Mayfield et al., 2018) were reported for the air-abrasive method compared to the control group. However, a higher patient satisfaction adopting the VAS was noticed for glycine decontamination (Merli et al., 2020). Contrary to these outcomes, other authors reported comparable improved peri-implant conditions for laser vs. air-abrasive treatments (Renvert et al., 2011), but complete disease resolution was not obtained in any of the reports (Schwarz et al., 2015; Ramanuskaite et al., 2021).

Six of the nine included publications addressed PICOS 1 (Merli et al., 2020; Karring et al., 2005; Renvert et al., 2009; Roccuzzo et al., 2022; Abduljabar et al., 2017; Alpaslan Yayli et al., 2022). Three studies from the same working group addressed the PICOS 2 question (Sahm et al., 2011; Schwarz et al., 2005; 2006). Nonetheless, adjunctive pocket irrigation with CHX solution (0.1%) and subgingival CHX-gel application (1%) was performed solely in the control group. Thus, the effect of additional measures/interventions to the investigated mechanical/physical decontamination methods was not really addressed in any of the included studies and no clear specifications/conclusion can be made on this aspect.

No studies were found answering the PICOS 3 question. This may be related to the fact that, considering the non-linear and accelerating progression pattern of peri-implantitis (Derks et al., 2016), it would be ethically questionable to perform studies where such lesions remain untreated submarginally for a period of 6 months.

One aspect that has to be emphasized is that the clinical assessments may have been influenced by several factors such as the type of prosthetic suprastructure/abutment or cementation (Monje, Amerio, et al., 2021). The type of restoration, respectively the dental patient situation (partially vs. fully edentulous) or prosthetic fixation, have been reported by the majority of the included studies (Renvert et al., 2009; Sahm et al., 2011; Alpaslan Yayli et al., 2022; Schwarz et al., 2006; 2005; Roccuzzo et al., 2022). Furthermore, in one study (Merli et al., 2020), the suprastructure had been removed at the timepoint of treatment but not at follow-ups, thus potentially limiting the accuracy of measurements. On the other hand, considering that calibration had been described and reported in all studies, and that clinical measurements were performed by the same blinded examiner, quality and reliability of the reported clinical assessments may be improved.

Along these thoughts, we should also mention that implant surface characteristics may have influenced treatment outcomes (Garaicoa-Pazmino, Lin, Alkandery, Parra-Carrasquer, & Suarez-Lopez Del Amo, 2021). Only one study, that was not included in this review, assed the influence of surface characteristic on the outcome of bone level and PD changes, failing to show any significant differences (Renvert et al., 2011). On the other hand, the application of a treatment protocol on implants with the same macro and micro-design characteristics might have increased the internal validity of the obtained results but at the same time limited the external validity of such protocol (Roccuzzo et al. 2022). Consequently, this important confounding factor should be carefully addressed and taken into consideration when analyzing the obtained data.

Limitations

Considering the aforementioned inclusion criteria, only a limited number of studies was found suitable to be included in this systematic review. Despite the recommendations of the 8th European Workshop on Periodontology in 2012, where parallel arm RCTs were recommended for determining therapeutic effects in non-surgical treatment of peri-implantitis and a minimum observation time for RCTs of at least 6 months reporting on composite endpoints, these aspects were not always considered in the majority of the studies (Sanz et al., 2012). Based on these recommendations, we included in this systematic review only studies reporting on a minimum of 6 months with clear disease definitions. This led however to a limited number of included studies addressing the first two focused questions and to no study answering the third one.

Moreover, the use of standard control therapies or of composite outcomes was also not always considered, and various combinations of adjunctive measures led also to exclusion of several studies and contributed to the high heterogeneity of the studies excluding thus the possibility for a quantitative analysis. Nonetheless, all included studies reported on the main outcome variables BOP and PD.

Further heterogeneity has been observed in the used case definitions. Despite the fact that all authors considered for their case definitions the parameters PD, BOP/SOP and MBL, a variety in extent and severity was observed. Furthermore, the lack of reporting on smoking status and periodontal condition of the included patients, contributed to protocol inconsistencies supporting our decision in not performing a quantitative analysis.

Randomization by coin toss in one study (Schwarz et al., 2005) provided a moderate risk of bias in the randomization process. Nonetheless, it is important to emphasize that the lack of a stratified randomization led to a large heterogeneity in the baseline patient characteristics and disease severity, thus limiting the possibility to draw clear recommendations. Despite these limitations, all included studies demonstrated a low risk of bias according to the Risk of Bias 2.0. tool (Sterne et al., 2019).

Conclusion

Available evidence on efficacy of non-surgical submarginal peri-implant instrumentation with mechanical/physical decontamination is limited by a low number of controlled studies and a high heterogeneity of study protocols. Clinical and patient-reported benefits remain to be demonstrated.

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Tables

Table 1

Included studies on non-surgical peri-implantitis therapy by laser therapy and/or submarginal mechanical/physical instrumentation.

No.	Publication First author Year Country	Study type Design Setting* Examiner Calibration Funding	Population *n* patients (n females; n patients per treatment arm) mean age ±SD (range) Periodontal diagnosis/status Smoking	Implants *n* implants mean age of implants type of restoration (single crown, bridge, RPD, RTD, FTD) implant material/brand type of fixation (screw retained/cemented)	Diagnosis Case definition IS TS RP	Period Total time of observation Follow-up intervals	Test Type of submarginal instrumentation Timepoint of administration (frequency) Additional measures (type, frequency)	Control Type of submarginal instrumentation† Timepoint of instrumentation (frequency) Additional measures (type, frequency)	Outcome PPD (mean, SD) BOP (mean, SD) SOP (mean, SD) MBL (mean, SD) PROMs IS TS RP	Comments Additional relevant information Conclusion
1.	Abduljabbar et al. 2017 Saudi Arabia	RCT parallel design University Same examiner, blinded and calibrated Calibration: kappa 0.92 Only non-smokers	63 male patients: C: 32 T: 31 Mean age: C: 43.6 y (31-58Y) T: 40.5 y (29-60 y) Periodontal diagnosis/status: NR	74 implants Mean age: C: 4.4y (2-6.5y) T: 4.8 y (1-5.3 y) in function Restoration: NR Implant type/material: platform-switched bone level (Straumann®),	BOP≥30% at periimplant sites PD≥4 mm and/or bone loss ≥3 mm	Duration: 6 m Follow-up: 3m, 6m	Nd:YAG laser (single application): pulsed, 1064 nm, 300 µm wide fiber, 4Watt, 80 mJ/pulse, pulse width 350 ms, repetition pulse 50 Hz, under	Mechanical debridement with plastic curettes	PPD (mm) Baseline: C: 5.6 (range 4-6) T: 5.3 (range 4.4-6) 3m: C: 4.5 (range 2.5-6) T: 2.4 (range 2-3) p<0.05 6m: C: 4 (range 3.8-5.5) T: 2.5 (2-3) p>0.05 BOP (%) Baseline	Nd:YAG therapy led to a more effective reduction of the periimplant soft tissue inflammation parameters than mechanical debridement alone

		Funding: NR	Smoking: NR	moderately rough surface			air + water cooling		C: 48.6 (range 39.6-55.7) T: 50.3 (range 36.3-58.2) 3m C: 16.5 (range 10.2-22.6) T: 5.5 (2.5-8.6) p<0.05 6m: C: 8.8 (range 6.9-10.3) T: 10.5 (range 7.4-12.5) p>0.05 SOP: NR MBL (mm): Baseline C: 1.8 (range 0.8-2.5) T: 2.1 (range 1.4-2.6) 6m: C: 1.7 (range 1-2.4) T: 2.2 (1.5-2.7) p>0.05 PROMs: NR IS: NR TS: NR RP: NR	
2.	Alpaslan Yayli et al. 2022 Turkey	RCT parallel design University Same blinded, calibrated examiner Calibration: 30 non-trial implants (correlation	*50* patients (21 female, 16-17/group): C: n=17 T1 (diode laser): n = 16 T2 (Er,Cr:YSGG): n = 17 mean age 50.52 ± 9.18y	50 implants Implant age: NR type of restoration: cement-retained ceramic bridge prosthesis for at least 6 months supported by ≥2 implants implant:	PPD 4–6 mm BoP + +/- suppuration bone loss 2–3 mm IS: NR TS: NR RP: NR	Duration:6 m Follow-up: 1m, 3m, 6 m	titanium Gracey curettes + T1: Diode laser (940 nm, tip 300µm, E-3-9mm, 0.8 W, 3 J/cm^2) T2: Er,Cr:YSGG (Waterlase	mechanical therapy alone (titanium Gracey curettes) + non-activated laser Timepoint of instrumentation: single	PPD (mm] Baseline C: 4.14 ± 0.64 T1: 4.14 ± 0.80 T2. Er,Cr:YSGG: 4.48 ± 1.14 6 m: C: 3.62±0.71 T1: 3.28±1.99 T2: 1.16±0.64 PPD reduction (mm) C: 0.53 ± 0.44 T1: 0.86 ± 0.59	no additional benefit by addition of diode laser Er,Cr:YSGG laser seems to be more efficient in PPD-reduction but not with

		coefficient 0.89-0.97) Funded by authors and by Van Yuzuncu Yil University, Van, Turkey Project No: TSA-2019–8343.	C: 50.36 ± 6.85 y T1: 46.50 ± 11.34 y T2: 54.71 ± 7.34 y Periodontal diagnosis/status: NR Non Smokers	Implant Direct® (CA, USA) Sandblastd, SLA surface type of fixation: cemented			2780 nm, 500 µm RFPT 5-14 mm, 1.5W, 30 HZ, 50% water, 40% air, 140µs puls time, 1 cm spot size) Single administration at baseline	Additional measures: None	T2: 1.16 ± 0.64 T2 stat. sign. higher reduction than C and T1 (p=0.032) BOP (%) Baseline C: 72.02 ± 23.93 T1: 88.09 ± 17.82 T2: 100.00 ± 0.00 6 m C: 60.71±29.13 T1: 61.90±29.37 T2: 51.19±19.84 BOP-reduction C: 11.31 ± 21.58 T1: 26.19 ± 33.94 T2: 48.81 ± 19.84 No stat sign. difference between the groups SOP: NR MBL: NR PROMs: NR IS: NR TS: NR RP: NR	respect to BoP
3.	Renvert et al. 2011 Sweden	RCT parallel design University Examiner: same blinded investigator Calibration: NR Funding: EMS, Kavo, Philips	42 patients (gender distribution NR, 21/group) Mean age: T: 68.5 ± 6.4 y C: 68.9 ± 12.5 y Periodontal diagnosis/status: NR, however if any periodontal lesions were	100 implants (T: 55; C: 45) Implant age: NR Restoration: NR Implant type/surface: machined surface: n=55 medium surface: n=41, rough surface: n=14	Bone loss > 3mm, PPD≥ 5 mm, BOP and/or SOP TS: PPD reduction ≥ 0.5 mm + gain/no further loss of bone IS:	Duration:6 m Follow-up: 6m	Er:YAG laser 100 mj/pulse, 10 Hz (12.7 J/cm^2), cone-shaped sapphire tip (T)	Amino acid glycine powder (Perio-Flow) with subgingival nozzle for 15 s (C)	PPD (mm) Reduction at 6 m T: 0.9 ± 0.8 C: 0.8 ± 0.5 p=0.55 BOP (%) Baseline: 1 BOP point: 5.1% line BOP: 37.8% drop BOP: 57.1% 6m: T: No BOP at 30.9% sites	Suprastructure was removed before parameter assessment and treatment. Treatment was performed by a dental hygienist.

			present these were treated before study enrolment Smoking: NR no differences between groups	machined surface: n=45 medium rough surface n=29 fixation: all screw-retained	Patient level: PPD reduction≥5 mm and gain/no loss of bone IS-Implant level: No PPD≥5 mm, no BOP/SOP at 6m RP: NR				C: 25% BOP SOP (%) Baseline: T: 30.9 C: 31.1 6m: T: 10.9 C: 11.1 p=0.42 MBL (mm) Loss baseline-6m T: 0.3±0.9 C: 0.1±0.8 p>0.05 PROMs: NR IS: no implants were lost TS: Implant level: T: 44% implants C: 47% implants RP: NR	All patients performed oral hygiene with the same sonic electric toothbrush. The clinical treatment results were limited and similar between the two methods compared with those in cases with severe peri-implantitis.
4.	Schwarz et al. 2006 Germany	RCT, parallel design University Same calibrated examiner Calibration: At 5 patients with each 2 implants Funding: grant “Arbeitsgemeinschaft für Kieferchirurgie innerhalb der	20 patients T: (7; 10) C: (5;10) C: 52±11y T: 56±14y Periodontal diagnosis: NR, however in chronic periodontitis patients subgingival tooth debridement was performed	40 implants (20/group) Mean age of implants: T: 5.1±2.2 years C: 4.2±3.4 years partially edentulous: T: 8, C: 8; fully edentulous: T: 2; C: 2; Exact prosthetic restoration: NR IMZ Twin Plus ® ITI (SLA, TPS)®	(m) Moderate (>4 mm)/ (a) advanced (>7 mm) peri-implant bone loss, BOP, suppuration IS: NR TS: NR RP: NR	Duration: 12 m Follow-ups: 3 m, 6 m, 12 m	Er:YAG laser (100 mJ/pulse, 10 Hz, 2.94µm)	Plastic curettes Chlorhexidine digluconate (0.2%)-irrigation+gel application, post-operative rinsing	PPD (mm) Baseline: T: (m) lesions: 4.6±0.9 (a) lesions: 5.9±0.9 C: (m): 4.5±0.8 (a): 6.0±1.3 12m: T: (m) 4.1±0.4 (a): 5.5±0.6 C: (m): 4.3±0.5 (a): 5.6±0.9 PPD reduction p>0.05 at 3, 6, 12 m BOP - Significant improvements at 3, 6,	Despite significantly higher BOP reduction in the laser group, its effectiveness was limited to 6 m, especially in severe peri-implantitis lesions

		Deutschen Gessellschaft für Zahn-, Mund- und Kieferheilkunde»	prior to study intervention No smokers	Spline Twist (MTX)® ZL-Duraplant (Ticer)® Camlog (Screw Line)® Fixation type: NR					12 m in both groups: (m) lesions p<0.001; (a) lesions p<0.01 - stat. sign. higher mean BOP reduction in T than C at 3- and 6 m: (m) p<0.01; (a) p<0.05 - increase of mean BOP at 6m and 12 m (p>0.05) SOP - 2 patients (4 implants) in group C were discontinued due to suppuration MBL: NR PROMs: NR IS: NR TS:NR RP: NR	
5.	Schwarz et al. 2005 Germany	RCT, Parallel design University Examiner: same blinded calibrated examiner Calibration: at 5 patients with min. 2 implants with PPD ≥4mm Funding: NR	20 patients (8 female; 10/group) Mean age: 50 years T: 48 years C: 51 years Periodontal diagnosis: NR However, in chronic periodontitis patients subgingival tooth debridement was performed	32 implants (16/group) Implants mean age: T: 4.1 years C: 4.3 years SLA surface: T: 9 C: 8 TPS surface: T: 7 C: 8 Restorations for partially (T: 6; C: 5) or fully	PPD≥4mm, loss of supporting bone, BOP, suppuration IS: NR TS: NR RP: NR	Duration: 6 m Follow-ups: 3m, 6m	Er:YAG laser (KEY 3® Kavo, Biberbach, Germany) 2.94 µm, 100mJ/pulse-12.7 J/cm^2, 10 pps with cone shaped glass fiber tip (85 mJ/pulse at the tip)	Plastic curettes Chlorhexidine digluconate (0.2%): pocket irrigation, gel application, mouth rinses for 2 weeks	PPD (mm) Baseline T: 5.4±1.2 C: 5.5±1.5 3m T: 4.6±1.1 C: 4.9±1.4 6m T: 4.6±1.1 C: 4.8±1.4 - No sign. differences between the groups (p<0.05) - Deep pockets (≥7 mm) showed the greatest changes BOP (%) Baseline	After 6 m, both treatments resulted in significant improvements; Er:YAG laser treatment showed stat. significantly higher reduction in BOP than C.

			prior to study intervention Smoking: NR	edentulous (T: 4; C: 5) arches Fixation type: NR					T: 83 C: 80 3m T: 30 C: 60 6m: T: 31 C: 58 - Sign. higher BOP reduction in T than C at 3m and 6m (p<0.001) SOP: -persisting suppuration in 1 patient (2 implants) in C MBL: NR PROMs: NR IS: NR TS: NR RP: NR	
6.	Roccuzzo et al. 2022 Switzerland	RCT, double-blinded parallel design University Same calibrated and blinded examiner Calibration NR Funding: ITI grant Nr 1374-2019	25 patients (12 female; T:12 of which 6 female; C: 13 of which 6 female) Mean age (years): 64±12.9 T: 67.3±12.2 C: 61.0±13.2 Periodontal status: History of treated periodontitis Smoking: n=5 patients ≤10 cigarettes/day (T: 3; C: 2)	25 implants T:12; C: 13) Tissue level implants with SLA surface (Straumann Dental) Cemented: 16: T:8; C: 8; screw-retained: 9: T: 4; C: 5	PPD>5mm BOP and/or suppuration Radiographic bone loss ≥2 mm TS: PPD≤ 5 mm, BOP- or PPD≤ 4 mm, no further bone loss at 6 m	Duration:6 m Follow-ups: 3m, 6m	Mechanical debridement with titanium curettes + stainless steel curettes for soft tissue+ rinsing with sterile saline solution+diode laser for 90s (819 nm, 2.5W, 50 Hz, 10 ms), 0.4	Mechanical debridement with titanium curettes stainless steel curettes for soft tissue+ rinsing with sterile saline solution +non-activated same diode laser	PPD (mm) Baseline: T: 5.40±0.91 C:5.29±0.52 3m T: 4.28±0.58 C: 3.76±0.60 Change Baseline-3m: T: -1.13±0.80 C: -1.54±0.51 6m: T: 4.13±0.82 C: 3.82±0.88 Change Baseline-6m: T: -1.28±0.70 C: -1.47±0.68 No stat. sign. group differences BOP (%)	Repeated adjunctive application of a diode laser in the non-surgical Treatment of periimplantitis did not show significant benefits compared with mechanical instrumentation alone.

		mm thick fiber Laser treatment was performed thrice within 14 days (Baseline, 7 and 14 days) Treatment was repeated in case of supporation	Baseline T: 62.5±30.3 C: 62.8±21.7 3m T: 52.8±34.7 C: 43.6±14.5 Change Baseline-3m T: -9.7± -36.5 C: -19.2±21.3 6m T: 47.1±33.2 C: 47.4±27.9 Change Baseline-6m T: -15.3±30.5 C: - 15.4±31.5 No stat. sign. group differences SOP (%) Baseline T: 58.3±51.5 C: 38.5±50±6 3m T: 8.3±28.9 C: 15.4±37.6 Change Baseline-3m T: -50±52.2 C: -23.1±43.8 6m T: 16.7±38.9 C: 7.7±27.7 Change Baseline-6m T: -41.6±51.5 C: -30.8±48.0 No stat. sign. group differences MBL (mm) (mean mesial+ distal aspect) Baseline T: -2.09±1.00 C: -2.04±0.48

			6m T: -2.05±0.95 C: -2.02±0.59 Change 6m-Baseline T: 0.004±0.50 C: 0.03±0.23 Not stat. sign. TS 6m T: 41.7% (n=5) C: 46.2% (n=6) P=0.821 PROMs: NR IS: NR RP: NR

*university/practice; †, hand instruments or (ultra)sonic instruments or air polishing e.t.c.; BOP, bleeding on probing; SOP, suppuration on probing; PPD, peri-implant probing pocket depth; MBL, marginal bone level; PROMs, patient-reported outcome measures; RPD, removable partial denture; RTD, removable total denture; SD, standard deviation; IS, implant survival; TS, treatment success; RP, resolution of peri-implantitis; SLA, sandblasted, large-grit, acid-etched surface, m, months; y, years, stat. sign., statistically significantly

Table 2.
Included studies on non-surgical peri-implantitis therapy with ultrasonics/air-abrasive systems therapy and/or submarginal mechanical/physical instrumentation.

	Publication First author Year Country	**Study type** Design Setting* Examiner Calibration Funding	**Population** *n* patients (n females; n patients per treatment arm) mean age ±SD (range) Periodontal diagnosis/status Smoking	**Implants** *n* implants mean age of implants type of restoration (single crown, bridge, RPD, RTD, FTD) implant material/brand type of fixation (screw retained/cemented)	**Diagnosis** Case definition IS TS RP	**Period** Total time of observation Follow-up intervals	**Test** Type of submarginal instrumentation Timepoint of administration (frequency) Additional measures (type, frequency)	**Control** Type of submarginal instrumentation† Timepoint of instrumentation (frequency) Additional measures (type, frequency)	**Outcome** PPD (mean, SD) BOP (mean, SD) SOP (mean, SD) MBL (mean, SD) PROMs IS TS RP	**Comments** Additional relevant information Conclusion
1.	Merli et al. 2020 Italy	RCT-mono-center 2-factorial parallel design Private practice examiner-blinded examiner calibrated	64 patients (40 females, 16 patients/group): C: non-surgical debridement alone T1: Non-surgical debridement and desiccant material (H); T2: Non-surgical debridement and glycine powder (G);	48 implants type of restoration: NR Implant brand: Thommen, Nobel type of fixation: NR	Max. PPD: 5-8 mm, BoP+/- Suppuration radiographic bone loss beyond changes from initial bone remodelling radiographic infra-osseous	6 months Follow-up supragingival prophylaxis: 1 week, 1 m, 3 m, 6 m	non-surgical debridement with ultrasonic scalers *plus* desiccant (T1=H) glycine powder (T2=G); glycine powder and	non-surgical debridement with ultrasonic scalers (C)	PPD (mm) Baseline Total (n=64): treatment arm: C: 4.4±1.1 T2: 5.1±1.5 (G); 6 m PPD reduction Total (n=58): 0.4±0.8 treatment arm: C: 0.2±0.7 (C); T2: 0.1±0.9 (G);	Additional relevant information procedures were performed following prosthetic removal Conclusion:

	provided desiccant material: HybenX®	T3: Non-surgical debridement, glycine powder and desiccant material (HG).) <u>mean age ±SD</u> range: NR treatment arm: 1. 64.5 (8.3) (C); 2. 60.3 (10.7) (H); 3. 66.4 (9.4) (G); 4. 60.3 (8.5) (HG).) Treated Periodontitis Smoking less than 20 cigarettes in ≤ 25% of the patients	defect ≤ 5 mm Radiographic suprabony defect ≤4mm IS: 100% TS: composite success criteria: implant survival, no PD≥5mm with BOP/SOP, no bone loss RP: NR	desiccant material (T3=HG).	Site BOP Baseline treatment arm: C: 3.3±0.8 (C); T2: 3.6±0.8 (G); 6 m BoP reduction Total (n=58): 0.6±1.3 treatment arm: C: 0.4±0.9 (C); T2: 0.7±1.3 (G); SOP (%) Baseline Total (n=58): 6/58 (10%) treatment arm: C: 4±25 (C); T2: 4±25 (G); 6 m SOP treatment arm: C: 2±12 (C); T2: 2±15 (G); MBL Baseline treatment arm: C: 3.3±1.2 (C); T2: 3.6±1.7 (G); 6 Months MBL-reduction Total (n=58): −0.0±0.8 treatment arm: C: 0.2±0.8 (C); T2: 0.2±1.0 (G);	minor or no differences between treatments with low success rate.

							PROMs: VAS pain (during treatment) Total (n=64): 3.6±2.7 treatment arm: C: 2.1±2.1 T2: 23.9±2.7; VAS pain (after 1 week) Total (n=64): 1.2±1.9 treatment arm: C: 0.6±1.0; T2: 1.8±2.5; VAS satisfaction at 6m: C: 6.9±2.6 T2: 7.5±3.0 OHIP-14 Baseline: C: 4.4±5.7 T2: 2.6±3.8 reduction at 6m: C: 1.8±6.1 T2: 4.0±6.4 Failures: Total (n=58): 2/60 (3%) treatment arm: C: 0 (0%); T2: 2 (13%); TS : Total (n=58): 17/56 (30%) treatment arm: C: 6 (37%); T2: 2 (14%);

2.	Renvert et al. 2009 Sweden	RCT parallel design University Examiner: same blinded investigator Calibration: NR Funding: Clinical Research Foundation	37 patients (T: 7 female; 18; C: 7 female; 19) 31 patients completed the study: T: 17; C: 14 Mean age: T: 62.7 ± 12.1y C: 60.3 ± 12.9y Periodontal diagnosis/status: NR Smokers: T: 3 C: 2	31 implants (T:17; C: 14) Implant age: NR Restoration: total prostheses: n=9 Partial prostheses: n=27 Implant type/surface: Nobel (n=24), Astra (n=6), other (n=1) Fixation: NR	Bone loss <2.5mm, PPD≥ 4mm, BOP and/or SOP IS: NR TS: NR RP: NR	Duration 6 m Follow-up: 1-3 m	Mechanical debridement with an ultrasonic device (Vector system) Polishing with rubber cups and polishing paste	Mechanical debridement with titanium curettes Polishing with rubber cups and polishing paste	PPD (mm) Baseline C: 4.0 ± 0.8 T: 4.3 ± 0.6 3 m: C: 4.0 ± 0.8 T: 4.1 ± 0.6 6 m: C: 4.0 ± 0.8 T: 3.9 ± 0.8 p= 0.97 BOP Baseline C 1.7 ± 0.9 T: 1.7 ± 0.6 3 m: C: 1.4 ± 0.9 T: 1.2 ± 0.7 6 m: C: 1.4 ± 1.0 T: 1.2 ± 0.7 p= 0.14 SOP: NR MBL (mm) Baseline: T: 1.5 C: 1.5 No implant displayed bone loss≥ 2.5mm PROMs: NR IS: NR TS: NR RP: NR	No differences were detected in treatment outcomes between the two treatment methods Oral hygiene and bleeding scores remained poor. No change in the total bacterial load.
3.	Karring et al. 2005 Denmark	RCT Split-mouth design University	11(gender NR; 11/group) 50-78 years Treated periodontitis	22 implants Mean age of implants: 3-11 years, average 7 years	PPD≥5 mm, BOP positive, ≥1.5 mm radiographic bone loss, exposed	Duration:6 m Follow-ups: 3m, 6m	2- 3 min instrumentation with Vector® system (∅ 0.8mm straight;	2- 3 min instrumentation with carbon fiber curette (∅ 0.8 mm)	PPD (mm) Baseline T: 5.8±1.1 C: 6.2±1.6 3m T: 6±1.5 C: 6.4±2.3	Despite the greater reduction in the number of bleeding sites in the T group, no

		same blinded examiner recorded all follow-ups calibration: NR Funding: supported by Dürr Dental (Bietigheim-Bissingen, Germany)	Smoking: 4 patients	Restoration: NR Implant brand: 2 pairs: Brånemark 4 pairs: ITI 5 pairs: Astra	implant threads IS: NR TS: NR RP: NR		1.3x0.5mm flexible carbon fiber tip combined with aerosol spray Vector® fluid polish with hydroxyapatite (∅ 10 µm) Treatment repeated at Baseline, 3m	Treatment repeated at Baseline, 3m	6m T: 5.8±1.2 C: 6.3±2.2 BOP (n/%) Baseline T: 7 /63.6 C: 8 /72.7 3m T: 6 /54.6 C: 8 /72.7 6m T: 4 /36.4 C: 9 /81.8 SOP: NR MBL (mm) Baseline T: 6.8±1.7 C: 7.4±2.1 6m T: 7.1±1.9 C: 7.7±2.6 PROMs: NR IS: NR TR: NR RP: NR	significant differences between the methods were found.
4.	Sahm et al. 2011 Germany	RCT parallel design University Same blinded calibrated examiner Calibration: in 5 patients each with min. 2 implants, 48	32 edentulous patients (20 female, C: 20, T: 23) Mean age: 60.6±38.6 y Periodontal status: treated chronic periodontitis and in proper	43 implants Implant age: Restoration: Implant material/type: cylindrical screw-machined surface, cylindrical scre-microrough	PPD≥ 4mm, BOP, SOP, radiographic bone loss ≤ 30% from the implant placement Min 2 mm leratinized attached mucosa IS: NR	Period: 6m Follow-ups: 3m, 6m	Oral hygiene program (supramucosal professional implant cleaning with rubber cups+polishing paste)- 2-4	Oral hygiene program (supramucosal professional implant cleaning with rubber cups+polishing paste)- 2-4 appointments	PPD (mm) Baseline: T: 3.8±0.8 C: 4±0.8 3m: T: 3±0.7 C: 3.2±1 Baseline-3m: T: 0.8±0.5 C: 0.8±0.9 6m: T: 3.2±0.9 C: 3.5±0.8	Both treatment procedures showed comparable but limited CAL-gains at 6 m, and significantly higher BOP reductions in the

	apart measurement Funding: partly funded by Electrical Medical Systems (EMS, Nyon, Switzerland)	supportive periodontal therapy Smoking: NR	surface, cylindrical-stepped scriew-microrough surface, cylinidrical screw-microrough surface, tapered screw-microrough surface Fixation: NR	TS: NR RP: NR	appointments Subgingival (nozzle, 1.7cm long, 0.8mm diameter tip) application for 5s of amino acid glycine powder (10%, 50% and 90% volume median particle size)	Mechanical debridement with carbon curets +pocket irrigation with 0.1% chlorhexidine digluconate solution +1% CHX submucosal application	Baseline-6m: T: 0.6±0.6 C: 0.5±0.6 BOP (%) Baseline T: 94.6±15.8 C: 95.3±9.6 3m: T: 43±29 C: 70.4±29.8 Baseline-3m: T: 51.6±28.6 C: 24.8±29.8 6m: T: 51.1±24.7 C: 84.3±15.5 baseline-6m: T: 43.5±27.7 C: 11.0±15.7 SOP: NR MBL: NR PROMs: NR IS: NR TS: NR RP: NR	Glycine group

Table 3
Excluded studies and reason for exclusion

No.	Publication	Reason for exclusion
1	Alqahtani et al 2020 32369570	Methodological issues in reporting data
2	Bach et al. 2000 11307411	protocol does not fit with stated focused question, surgical therapy of peri-implantitis
3	Hentenaar et al. 2020 **32794356**	Follow-up < 6m (3 m)
4	Hentenaar et al 2021 33844373	Evaluation of non-surgical and surgical treatment, protocol does not fit with stated focused question
5		
6	Hussain et al 2022 34710240	Periodontal treatment, protocol does not fit with stated focused question,
7	John et al. 2017 28453869	Therapy of peri-implant mucositis and peri-implantitis, total number of subjects n=27 (does not fit the inclusion criteria)
8	John et al. 2015 25605425	No 6 m data
9	Koldsland et al. 2020 32767565	therapy on SPT after surgical treatment, protocol does not fit with stated focused question
10	Levin et al. 2015 25262677	Follow-up < 6m (3 m)
11	Lupi et al. 2016 26842543	protocol does not fit with stated focused question, therapy on SPT
12	Machtei et al 2021 33111988	Antiseptics (Chlorhexidin chips), protocol does not fit with stated focused question
13	Mayer et al. 2020 32185910	Antiseptics and local antibiotics, protocol does not fit with stated focused question
14	Mettraux et al. 2016 doi: 10.1111/clr.12689	Does not meet the inclusion criteria (subjects n=15)
15	Persson et al. 2010 20507380-microbio	Microbiological findings, endpoints do not match the inclusion criteria
16	Pulcini et al 2019 30779246	protocol does not fit with stated focused question, therapy of peri-implant mucositis
17	Renvert et al. 2006 16634959	protocol does not fit with stated focused question, comparison to local antibiotics
18	Roos-Jansaker et al. 2017 26013241	protocol does not fit with stated focused question, application of antiseptics (Perisolv)

19	Schwarz et al. 2006 16634072	protocol does not fit with stated focused question, therapy of mixed peri-implant mucositis and peri-implantitis
20	Schwarz et al 2006 DOI 10.1002/lsm.20347	Does not meet the inclusion criteria (subjects n=12)
21	Schwarz et al. 2015 doi: 10.1111/jcpe.12439	protocol does not fit with stated focused question, therapy of peri-implant mucositis and peri-implantitis
22	Soriano-Lerma et al 2020 31577041	Follow-up < 6 m (45 days)
23	Strauss et al 2021 34328476	Adjunctive antibiotics, no 6m data, protocol does not fit with stated focused question
24	Zeza et al. 2017 28497660	total number of subjects n=15
25	Tang et al. 2002 12419136	protocol does not fit with stated focused question, comparison to local antibiotics
26	Wohlfart et al. 2017 DOI 10.1186/s40729-017-0098-y	protocol does not fit with stated focused question, treatment was repeated at 3 m, the 6 m data represent the 3 m evaluation after the second treatment
27	Yang et al 2021 34876432	Effect on plaque removal, protocol does not fit with stated focused question, mixed peri-implant mucositis and peri-implantitis

m, mo; SPT: supportive periodontal therapy

Table 4. Quality assessment (risk of bias across studies)

	Author/ Year	Study title	Bias arising from the randomisation process	Bias due to deviations from the intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall bias
1	Abduljabbar et al. 2017	Effect of Nd:YAG laser-assisted non-surgical mechanical debridement on clinical and radiographic peri-implant inflammatory parameters in patients with peri-implant disease	Authors' judgement: **Low Risk** Support for judgement: Randomization process and allocation are in detail explained	Authors' judgement: **Low risk** Support for judgement: protocol straight forward no clue of deviation	Authors' judgement: **Unclear risk** Support for judgement: All outcome data not available	Authors' judgement: **Low Risk** Support for judgement: Clear whether outcome assessors blinded	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**
2	Alpaslan Yayli et al. 2022	Erbium, chromium-doped: yttrium, scandium, gallium, garnet and diode lasers in the treatment of peri-implantitis: clinical and biochemical outcomes in a randomized-controlled clinical trial	Authors' judgement: **Low Risk** Support for judgement: Details about randomization process and allocation conducted by a software and sealing by envelope	Authors' judgement: **Low risk** Support for judgement: protocol straight forward no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: All outcome data available	Authors' judgement: **Unclear risk** Support for judgement: calibrated and blinded examiner not involved in the treatment	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**

3	Merli et al. 2020	Short-term comparison of two non-surgical treatment modalities of peri-implantitis: Clinical and microbiological outcomes in a two-factorial randomized controlled trial	Authors' judgement: **Low Risk** Support for judgement: Details about randomization process and allocation	Authors' judgement: **Low risk** Support for judgement: protocol straight forward no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: All outcome data available	Authors' judgement: **Low risk** Support for judgement: clearly stated who performed the treatment and who the outcome assessments	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**

	Author/ Year	Study title	Bias arising from the randomisation process	Bias due to deviations from the intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall bias
4	Renvert et al. 2011	Treatment of peri-implantitis using an Er:YAG laser or an air-abrasive device: a randomized clinical trial	Authors' judgement: **Low Risk** Support for judgement: Randomization conducted by a software	Authors' judgement: **Low risk** Support for judgement: protocol straight forward no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: All outcome data available	Authors' judgement: **Low risk** Support for judgement: calibrated and blinded examiner not involved in the treatment	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**
5	Renvert et al. 2009	Mechanical non-surgical treatment of peri-implantitis: a double-blind randomized longitudinal clinical study. I: clinical results	Authors' judgement: **Low Risk** Support for judgement: Randomization conducted by a software	Authors' judgement: **Low risk** Support for judgement: protocol straight forward no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: All outcome data available	Authors' judgement: **Low risk** Support for judgement: calibrated and blinded examiner not involved in the treatment	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**
6	Schwarz et al. 2006	Nonsurgical treatment of moderate and advanced periimplantitis lesions: a controlled clinical study	Authors' judgement: **Low risk** Support for judgement: Randomization conducted by a software	Authors' judgement: **Low risk** Support for judgement: no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: All outcome data available	Authors' judgement: Low **risk** Support for judgement: calibrated and examiner not involved in the treatment	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**

	Author/ Year	Study title	Bias arising from the randomisation process	Bias due to deviations from the intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall bias
7	Karring et al. 200[illegible]	Treatment of peri-implantitis by the Vector system	Authors' judgement: **Low Risk** Support for judgement: Randomization conducted with sealed enveloped	Authors' judgement: **Low risk** Support for judgement: protocol straight forward no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: All outcome data available	Authors' judgement: **Low risk** Support for judgement: examiner not involved in the treatment	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**
8	Schwarz et al. 2005	Clinical evaluation of an Er:YAG laser for nonsurgical treatment of peri-implantitis: a pilot study	Authors' judgement: **Moderate Risk** Support for judgement: Randomization conducted by tossing a coin	Authors' judgement: **Low risk** Support for judgement: protocol straight forward no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: All outcome data available	Authors' judgement: **Low risk** Support for judgement: calibrated and examiner not involved in the treatment	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**
9	Roccuzzo [illegible]22	Non-surgical mechanical therapy of peri-implantitis with or without repeated adjunctive diode laser application. A 6-month double-blinded randomized clinical trial	Authors' judgement: **Low risk** Support for judgement: Randomization conducted with sealed enveloped	Authors' judgement: **Low risk** Support for judgement: no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: All outcome data available	Authors' judgement: **unclear risk** Support for judgement: calibrated examiner not involved in the treatment	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**

	Author/ Year	Study title	Bias arising from the randomisation process	Bias due to deviations from the intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall bias
10	Salem et al. 2011	Non-surgical treatment of peri-implantitis using an airabrasive device or mechanical debridement and local application of chlorhexidine: a prospective, randomized, controlled clinical study	Authors' judgement: **Low Risk** Support for judgement: Randomization conducted with a software	Authors' judgement: **Low risk** Support for judgement: protocol straight forward no clue of deviation	Authors' judgement: **Low Risk** Support for judgement: all outcome data available	Authors' judgement: **Unclear risk** Support for judgement: examiner not involved in the treatment, details on the blinding not reported	Authors' judgement: **Low Risk** Support for judgement: Reported outcome data unlikely to have been selected	Authors' judgement: **Low risk**

Fig. 1 Flowchart of the study