Despite the high predictability and survival of dental implants at 10 and 20 years, there is a risk for complications, such as peri-implant mucositis and peri-implantitis (PI). These are inflammatory diseases affecting the osseointegrated implant and the local tissue, commonly a plaque-associated pathologic condition. The main difference between mucositis and peri-implantitis appears to be the presence of bone loss in the latter. PI eventually may result in implant loss and has been considered one of the most common reasons for implant failure.

Prevalence of PI is around 20% up to 14 years after implant placement, and typical signs and symptoms of PI may include the following: (1) a saucer-shaped defect with vertical crestal bone destruction along with a radiographic image of osseointegration on the apical part; (2) formation of a peri-implant pocket; (3) bleeding on probing (BOP) that may or may not be present upon gentle probing force (< 0.25 N); (4) mucosal swelling and hyperplasia; and (5) possible acute infection pain, although generally it is asymptomatic.

There is general concern related to the incidence of PI, which is increasing due to the increasing demand for implants. Moreover, it depends on the ability and expertise of the doctor, which raises another important question: How efficient are the available protocols for PI treatment? This is important to know in order to determine what treatment approach should be followed.

The basic steps in PI therapy include infection control, nonsurgical debridement, corrective/resective or regenerative/augmentative surgical procedures when necessary, and supportive treatment. After correct diagnosis, the primary objective is to modify the microbiota present at the implant surface to allow it to be tolerated by the host’s immune system.
The total elimination of pathogenic bacteria is the more effective approach.\(^{17}\) However, effective mechanical debridement is challenging to achieve.\(^{17}\) According to Smeets et al,\(^{18}\) several adjunctive nonsurgical therapies have been proposed to resolve the infection. Drug therapy with antiseptic rinses that contain chlorhexidine (CHX) or systemic/local antibiotics (ABs; eg, tetracycline, doxycycline, amoxicillin, metronidazole, minocycline hydrochloride, ciprofloxacin) have been explored in many in vitro and in vivo studies.\(^{19–27}\) Moreover, laser and photodynamic therapy (PDT) methods appear to be promising and can be used, but more studies are still required to evaluate the actual value of these therapies in the treatment of PI.\(^{18}\)

Surgical procedures have been proposed to enhance the treatment of PI, the healing potential, and/or tissue regeneration.\(^{17}\) Therefore, comparing the efficacy of nonsurgical versus surgical treatments, a systematic review with meta-analysis\(^{28}\) reported that nonsurgical methods did not reduce the probing depth (PD) but were effective at reducing soft tissue inflammation, as observed for BOP values. As for surgical procedures, most of the reviewed articles concerned regenerative treatments. The findings suggested that surgical treatment of peri-implantitis is more effective at reducing PD and BOP.

Although scientific evidence on the therapies’ efficacy to treat peri-implantitis is limited, clinical evidence suggests that it is predictable when diagnosis and intervention are made as soon as possible.\(^{17}\) The purpose of this overview of systematic reviews was to assess the best available literature that studied peri-implantitis. The ultimate goal is to try to find the best available treatment option for peri-implantitis when it comes to surgical (S), nonsurgical (NS), and adjunctive methods and to help the clinician handle it more efficiently in peri-implantitis cases.

**MATERIALS AND METHODS**

**Protocol Registration**
The protocol for this review was registered at PROSPERO (CRD42021236759). The basic methodology for the present study followed the guidelines from the Cochrane Handbook for Systematic Reviews of Interventions, and PRISMA guidelines were also taken into consideration.\(^{29}\)

**Focus Question**
The clinical question was elaborated following the search strategy and organized according to the PICO (population, intervention, comparison, outcome) strategy. The focus question was: “Could patients who underwent implant treatment and developed peri-implantitis (P) be approached with success only by nonsurgical treatment (I), or are better results achieved with surgical and adjunctive therapies (C), elevating the short- and long-term survival rates of dental implants (O)?”

**Search Strategy**
To review an adequate bibliographic base for the study and answer the research question and objectives, strict research criteria were established with well-defined inclusion and exclusion criteria. For this purpose, a bibliographic search was conducted through MEDLINE/PubMed, Web of Science, and Cochrane Evidence/Library, using specific terms and Boolean combination (AND, OR; Appendix Table 1; see Appendix in online version of this article at quintpub.com), to collect systematic reviews (SRs) published between January 2014 and January 2021 with an English language restriction. The articles obtained in the search on the databases mentioned above were imported to a citation management software (EndNote X9, Thomson Reuters) and then screened and analyzed.

**Inclusion and Exclusion Criteria**
This study was conducted based on other SRs of randomized controlled trials (RCTs) restricted to English language with a publication date from January 2014 to January 2021 and publication in journals with a peer-review system. Moreover, if the systematic review included articles other than RCTs, only peri-implantitis data from RCTs were included.

Exclusion criteria were SRs including only studies other than RCTs, studies that involved only mucositis, and abstracts or electronically posted information without full text.

**Screening Process**
Two review authors (B.G.S.M. and G.V.O.F.) performed independent searches and screenings. Analysis of titles and abstracts was the first step of the process. After that, full papers of the included works were read and analyzed according to the inclusion and exclusion criteria for subsequent data extraction. Any disagreement between authors was resolved by discussion with a third author (J.C.H.F.).

**Data Extraction**
Two authors (B.G.S.M. and G.V.O.F.) independently extracted, whenever available, the following data included in the SRs: authors; population of patients and implants; age of patients; case definition of PI; type of PI intervention (NS or S, with or without the aid of adjunctive measures) in test and control groups; follow-up period; study parameters concerning primary and secondary outcomes, including PD, clinical attachment level (CAL), BOP/sulcus bleeding index (SBI), marginal
Eligibility

Screening

Quality Assessment of the Systematic Reviews
The AMSTAR 2 tool was used to evaluate the methodology of each SR included in this study. Two authors (B.G.S.M. and G.V.O.F) reviewed them independently using the 16-item criteria (Appendix Table 2). Four options were available to answer each of the requirements: “yes,” “partial yes,” “no,” and “not applicable.” As AMSTAR 2 rating is not meant to generate an overall score and thereby evaluate studies by its weakest critical domain, only a final verdict was given to each SR.30

RESULTS

In total, 437 articles were initially found, of which 34 were retrieved for full-text reading. Twenty-five articles were excluded with justification shown in Fig 1, and nine SRs were included in this study, resulting in 98 RCTs within the SRs included (Appendix Table 3). They accounted for nonsurgical, surgical, and adjunctive measures to treat PI. As some of the SRs included repeated RCTs, the total number of non-repeated RCT articles was 59 (Table 1).

Nonsurgical treatments and adjunctive measures focused on cleaning the implant surface and detoxifying the peri-implant tissues. They involved manual debridement with CHX/saline/hydrogen peroxide, ultrasound debridement, air-abrasive systems with glycine powder, systemic or local ABs, antiseptics, and the use of laser systems. The NS interventions work best at removing local irritants in PI-affected tissues but do not prevent bone loss.

Surgical treatments found in the articles included were flap elevation and detoxification of the implant surface along with the use (or not) of AB agents, membranes, and grafting materials. The surgical methods can and were combined with NS/adjunctive techniques in several included primary studies.31–34 Figure 2 summarizes all data obtained according to each research and the suggested weight (circle size), indicating the best treatment to solve the PI question.

Nonsurgical Techniques
Six SRs included this type of treatment: Mahato et al (2016), Chala et al (2020),36 Khan et al (2020),33 Schwarz et al (2015), Kotsakis et al (2014),37 and Gao et al (2020).38 Six subtopics were created to ease comprehension and avoid repeating the RCT studies in cases where they were included in more than one systematic study, which can be observed in Table 1 and Appendix Table 3.

Nonsurgical systematic review 1: Mahato et al35
This SR reported 730 treated patients, with follow-ups ranging from 6 months to 4 years. The peri-implantitis diagnosis consisted of the following clinical findings: PD > 4 mm, bone loss (with radiographic confirmation) of at least 1.5 mm, exposed implant threads, no mobility, and presence of bacteria.

Regarding mechanical treatments and detailing each RCT included (n = 10) within this SR, Karring et al19 and Persson et al40 tested the ultrasound system versus carbon fiber curettes. After a 6-month follow-up, no significant changes were observed between the two methods, which were both insufficient to treat the peri-implantitis.

Sahm et al41 compared mechanical debridement used along with an antiseptic agent (MDA) versus powdered amino acid glycine (AAD). After a 6-month follow-up, comparable but limited improvement of CAL was achieved in both groups, and reduction in BOP was significantly greater in the AAD group than the MDA group.

Schwarz et al42 Renvert et al,43 and Persson et al44 compared Er:YAG laser with an air-abrasive device. After a 6-month follow-up, the authors found limited improvements in clinical parameters; however, the bacterial load was not reduced enough to control PI.

Regarding mechanical treatments associated with ABs, two studies were published by Renvert et al26,45 They evaluated mechanical treatment in 32 patients...
Table 1: Type of Treatment of Each RCT Included Within the SRs, Without Repetition

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<tr>
<th>SR RCTs analyzed</th>
<th>Nonsurgical treatment</th>
<th>Surgical treatment</th>
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<td></td>
<td>Sahm et al (2011)</td>
<td>Er:YAG laser versus an air-abrasive device</td>
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<td></td>
<td>Renvert et al (2006)</td>
<td>Photodynamic therapy (PDT) versus minocycline microspheres</td>
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<td>Sanz-Sánchez et al (2017)</td>
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AB = antibiotic; aPDT = antimicrobial photodynamic therapy; BMP = bone morphogenic protein; CHX = chlorhexidine; CPC = cetylpyridinium chloride; EMD = enamel matrix derivative; GBR = guided bone regeneration; HA = hydroxyapatite; PDGF = platelet-derived growth factors.
and compared microspheres with minocycline used locally against CHX gel debridement. One year after the treatment began, both studies showed significant improvement in Plaque Index, PD, and BOP. There was no difference between the initial and the final results regarding bacterial load and microbiota changes.

Schär et al.46 tried to compare the benefits of PDT over minocycline microspheres. In both groups, mucosal inflammation was significantly reduced after 6 months. The last RCT included was reported by Hallström et al.,47 who used systemic azithromycin for 4 days. After 6 months, only oral hygiene improved, and the study could not provide evidence.

Nonsurgical systematic review 2: Chala et al.36 Three RCTs were found comparing laser treatments versus nonsurgical options: Renvert et al.,43 Abduljabbar et al.,44 and Romeo et al.49 In the 3-month follow-up period, Renvert et al did not report any measurements; Abduljabbar et al provided PlqI, BOP, and PD, all with P < .05 between the groups. Romeo et al reported the same outcomes of clinical parameter improvements as Abduljabbar et al, but no P values were listed.

In the 6-month follow-up, Renvert et al showed a nonsignificant result for BOP and PD (P = .22 and P = .55, respectively) for the study group compared to the control group. Abduljabbar et al also revealed nonsignificant values (P > .05) for PlqI, BOP, and PD between the two groups. With this evidence regarding nonsurgical treatment, adjunctive laser therapy can improve the results at the 3-month mark, but no relevant improvement was noted after 6 months compared to regular treatment.

Nonsurgical systematic review 3: Khan et al.33 The authors investigated the nonsurgical techniques of the following primary studies: Arısan et al.,50 who analyzed mechanical debridement compared to adjunctive diode laser application; John et al.51 and Sahm et al.,41 who evaluated mechanical debridement with topical CHX versus an air-abrasive device with amino acid glycin powder; Machtei et al.,25 who studied mechanical debridement with matrix chips versus mechanical debridement with CHX chips; Renvert et al.43 with results of Er:YAG laser versus an air-abrasive device containing hydrophobic powder; and Roos-Jansåker et al.,52 who studied mechanical debridement versus adjunctive local application of chloramine gel.

After a follow-up at the 3-month mark, Roos-Jansåker et al.52 found no significant difference between manual debridement (ultrasonic and hand scalers) and the adjunctive usage of a chloramine gel for all clinical parameters studied. Although no statistical difference was found between the groups, they presented significant improvements in the evaluated clinical outcomes (PlqI, PD, CAL, and BOP).

Arısan et al.50 reached similar results, finding no statistically significant difference between conventional...
debridement and the adjunctive use of diode laser among the investigated parameters (PD, PlqI, and BOP). Both treatment modalities showed improvement across the same parameters at the 6-month follow-up compared to baseline data. The only parameter where a significant difference was found between groups concerned the MBL. In the laser group, participants showed a greater MBL after 6 months than the control group, despite no differences in the baseline values for both groups.

Machtei et al\(^\text{25}\) attempted to evaluate the effectiveness of a proposed treatment protocol for peri-implantitis. Affected sites were treated with application of chips containing CHX as an adjunctive aid to conventional debridement. They received either hydrolyzed gelatin matrix chips (MatrixC) or a biodegradable matrix containing CHX chips (PerioC). Clinical measurements took place at weeks 2, 4, 6, 8, 12, and 18 post-intervention, with the participants coming back for a final evaluation after 6 months. Reports showed that the PerioC group participants had a more significant improvement in PD ($P = .07$) and CAL gain versus the MatrixC group. No differences were detected between groups when comparing BOP, but both groups experienced substantial boosts across all clinical parameters over the 6-month follow-up. The authors concluded that the frequent placing of PerioC and MatrixC and mechanical debridement resulted in considerable improvement in sites with peri-implantitis.

John et al\(^\text{51}\) investigated air-abrasive treatment versus manual mechanical debridement with local application of CHX. The authors found that the devices using air abrasion significantly decreased the mean BOP scores compared to the conventional debridement technique. This result, however, was found to be an anomaly, as no differences were reported across PlqI, PD, marginal recession (MR), or CAL gain between groups. At the end of this 12-month study, the authors concluded that both treatment options were feasible, resulting in comparable and significant CAL gain. Air-abrasive devices also resulted in a greater reduction of BOP. Sahm et al\(^\text{41}\) performed the same investigation as John et al\(^\text{51}\) and reached similar conclusions with their study. At follow-up appointments, clinical measurements were taken at the 3- and 6-month marks. The group treated with the air-abrasive device had significantly lower BOP values when compared to the conventional debridement group. Other parameters, such as PI, MR, PD, and CAL gain, did not reveal any difference between groups.

Renvert et al\(^\text{53}\) compared the effectiveness of an air-abrasive machine versus an Er:YAG laser. Data revealed that both treatment options allowed for statistically significant improvement in clinical parameters, including BOP, SOP, PlqI, PD, and MBL, but no difference between the groups’ values.

**Nonsurgical systematic review 4: Schwarz et al.**\(^\text{37}\)

Alternative measures for biofilm detoxification were included in six RCTs. Renvert et al\(^\text{53}\) used the same type of treatment in the test group as Karring et al,\(^\text{39}\) employing an ultrasound device and a hydroxyapatite polish. Schwarz et al\(^\text{42}\) and Renvert et al\(^\text{43}\) described the Er:YAG laser used as a monotherapy. The studies from Renvert et al,\(^\text{43}\) Sahm et al,\(^\text{41}\) and John et al\(^\text{51}\) focused on air-abrasive therapy using glycine powder.

One RCT by Machtei et al\(^\text{35}\) evaluated adjunctive antibiotic treatment versus ultrasonic debridement. After CHX matrix applications at 2, 4, 6, 8, 12, and 18 weeks, the 6-month post-intervention follow-up revealed a more significant PD reduction with CHX chips than placebo chips, but the statistical significance was not reported.

As for adjunctive AB therapy with mechanical debridement, three RCTs were reviewed. Renvert et al (2006)\(^\text{26}\) and Renvert et al (2008)\(^\text{45}\) used minocycline microspheres applied one time or at 30 and 90 days and compared the results with the usage of 1.0% CHX gel. At 12 months post-intervention, both RCTs reported significantly higher reductions in the BOP in repeated AB applications and PD in a single AB application compared to the control therapy. Büchter et al\(^\text{34}\) found the same results as the two previous RCTs using doxycycline hyclate as an adjunctive measure to mechanical debridement.

Schrä et al\(^\text{46}\) and Bassetti et al\(^\text{23}\) compared the use of local AB treatment as an adjunctive measure, using minocycline microspheres, versus antimicrobial PDT (aPDT). At the 12-month follow-up, test and control groups revealed significant improvements in the evaluated parameters, but no clinical nor immunologic improvements were detected.

This SR detected that, in the nonsurgical treatment of peri-implantitis, there was a slight tendency to favor local antibiotic therapy or alternative methods of plaque removal, such as Er:YAG laser or glycine powder polishing. Nonsurgical treatment of peri-implantitis also generally failed to make any significant change in microbiologic improvements due to the high frequency of residual BOP scores at implant sites.

**Nonsurgical systematic review 5: Kotsakis et al.**\(^\text{37}\)

This SR included four primary studies. Renvert et al\(^\text{53}\) used an air-abrasive device as a control treatment of peri-implantitis in 100 sites. At the 6-month mark, PD did not show any significant improvements in intra-group or intergroup comparisons. On the other hand, BOP was significantly reduced in both groups.

Two other studies from Schwarz et al (2005 and 2006)\(^\text{42,55}\) used an identical treatment therapy, with Er:YAG laser to treat peri-implantitis. The control groups used mechanical debridement with plastic curettes and mouthwash with 0.2% CHX. The results suggested that a significant reduction of PD and attachment loss can...
be anticipated 6 months after the intervention. Still, at the 12-month mark, the improvements are not expected to be maintained. The mean reduction of PD and attachment loss was < 1 mm in both studies, and no significant difference was found between the test and control groups. However, reduction of BOP was significant compared to baseline values and significantly higher in the groups in which the Er:YAG laser was used.

**Nonsurgical systematic review 6: Gao et al.** This SR evaluated the additional effect of *Lactobacillus* probiotics in treating peri-implant diseases. Only two studies of this SR concerned the possible consequences of probiotic *Lactobacillus* in the treatment of peri-implantitis. The remaining articles were about the effect of this probiotic in peri-implant mucositis and therefore were not included in the present review.

Both studies took place in 2018, one in Spain (Galofré et al66) and the other in Japan (Tada et al57). Galofré et al found that BOP and PD, at the implant level, showed significant improvements after treatment in the probiotic group (with the nonsurgical intervention being subgingival debridement with an ultrasonic device using carbon tips and carbon curettes).

The study by Tada et al revealed that an essential decrease in PD was achieved after the probiotic was initiated, but the difference was not significant between groups; the same was observed in BOP values. The nonsurgical intervention comprised oral hygiene instructions, supragingival scaling, and azithromycin (500 mg once a day) for 3 days. The test group received the probiotic, and the control group received a placebo.

**Surgical Techniques**

Eight SRs included this type of treatment: Aljohani et al (2019), Mahato et al (2016), Chala et al (2020), Khan et al (2020), Schwarz et al (2015), Kotsakis et al (2014), Sanz-Sánchez et al (2017), and Tomasi et al (2019). Didactically, subtopics were created to ease comprehension. There was no repetition of RCT studies included in more than one systematic study, which can be observed in Table 1 and Appendix Table 3.

**Surgical systematic review 1: Aljohani et al.** The primary studies included involved the effectiveness of surgical regenerative interventions in treating peri-implantitis. Five studies were selected by Aljohani et al.32 They accounted for 200 patients (127 women and 73 men; mean age: 56 years; age range: 26 to 76 years) and 226 implants. Three out of the five studies noted the smoking status and history of periodontitis. Those three reported values ranging from 40.9% to 69.6% of the patient population who smoked, while 50% to 95.2% had a history of periodontal treatment or tooth loss due to periodontal disease.

In a study by Aghazadeh et al, autogenous bone grafts versus bovine xenografts were differentiated, using resorbable bovine collagen membrane in both groups. Two studies59,60 used porous titanium granules without a membrane. Two other studies used natural bone minerals with collagen membrane.

The detoxification methods used were 3% hydrogen peroxide and saline solution, 59,60 24% EDTA gel and saline solution, implantoplasty and Er:YAG laser, and saline solution only. The Wohlfahrt et al study63 used the submerged implant treatment, while the other four used a nonsubmerged technique. The patients received ABs (azithromycin, amoxicillin, or metronidazole) and CHX mouthwash postsurgically in all studies. Only Schwarz et al61 prescribed CHX and no AB.

Only the study by Wohlfahrt et al63 measured and noted the peri-implant keratinized mucosa. It was the only study to establish a weak positive correlation (r = 0.371) between existent keratinized mucosa and increases in peri-implant bone level.

It was reported that all interventions reduced PD significantly in all groups compared to baseline data. However, in all studies the reduction was insignificant (P > .05) between groups. The highest mean reduction was 3.1 mm, as reported by Aghazadeh et al,59 who used a bovine xenograft with a collagen membrane. The lowest mean reduction was 1.2 mm, reported by Schwarz et al,67 where implants were treated with an implantoplasty technique and saline solution.

The effect of the intervention on BOP was reported by four out of five studies, which verified a significant reduction compared to before treatment.59–62 Wohlfahrt et al63 reported no difference between the two groups (intergroup) nor compared to the baseline (intragroup). None of the studies noted a statistical reduction between tested groups, except Schwarz et al.61 The highest percentage reduction occurred in patients treated only with implantoplasty and saline solution (85.2% of reduction).62 In contrast, the lowest reduction was 25.9%, which occurred in the Class Ic defect group in the study by Schwarz et al.61

The effect of the intervention on RBL was not reported in two out of five studies.61,62 In the other three, evidence of increased bone level was obtained compared to baseline in all intervention groups. However, the increase was not significant in all groups. Two studies reported that porous titanium granules led to a significant rise in radiographic defect filling compared to control groups.

Aghazadeh et al59 indicated that using bovine xenograft led to an increase in defect fill versus the autogenous bone group. However, this increase was limited and relatively insignificant. The highest mean defect fill was reported in the porous titanium granules group (3.6 mm) by Jepsen et al.60 The lowest was found by Wohlfahrt et al,63 with a value of 0.1 mm in the control group.
In the conclusions of this SR, Aljohani et al\textsuperscript{32} said that regenerative surgical treatment revealed clinical improvements in the included studies when compared to pretreatment status. However, none of the selected studies proved statistical significance of their approach.

**Surgical systematic review 2: Mahato et al.**\textsuperscript{35} This SR included a surgical technique involving nine RCTs, but as two were already cited in the SR above, seven RCTs will be described in this study. Schwarz et al published two articles (2008 and 2009)\textsuperscript{64,65}; the first one had a 2-year follow-up, and the second had a 4-year follow-up. The 2008 study showed that both nanocrystalline hydroxyapatite and the combination of natural mineral bone plus a collagen membrane produced similar results regarding the significant clinical reduction of PD and CAL gain. In the 2009 study, on the other hand, the combination of natural bone minerals plus collagen membrane was revealed to be more efficacious in improvement of clinical parameters. Nonetheless, another study by Schwarz et al (2006)\textsuperscript{66} concluded that nanocrystalline hydroxyapatite and guided bone regeneration (GBR) improved clinical parameters.

Schwarz et al (2011 and 2012)\textsuperscript{67,68} did two peri-implantitis studies evaluating and comparing the efficacy of Er:YAG laser versus plastic curettes and cotton pellets soaked in sterile saline solution (CPS) for surface debridement/decontamination. In both procedures, the implantoplasty took place at the exposed implant surface. It was also used as an augmentation technique with natural bone minerals and collagen membranes. Twenty-four months after treatment, the CPS group showed a significant decrease in BOP, and the radiographic bone fill inside the bony defect was the same between groups. CAL values were different, but not significantly.

In the study by de Waal et al\textsuperscript{69} the authors showed adjunctive benefits when the addition of 0.12% CHX + 0.05% cetlypyridinium chloride (CPC) was made, comparing it to a placebo solution. After a resective surgical treatment, this solution was added with apical positioning of the flap, bone recontouring, and surface debridement. Although the suppression of anaerobic bacterial growth was more significant with the CHX and CPC solution, it did not lead to a significantly superior final clinical result.

Romeo et al\textsuperscript{70} tried to differentiate the efficacy of resective surgery versus implantoplasty. The 3-year follow-up suggested that there was significantly less MBL after implantoplasty treatment.

The conclusion reached by the SR by Mahato et al\textsuperscript{35} was that in more advanced cases of peri-implantitis, a combined surgical treatment of resective and regenerative procedures, followed by implant surface decontamination, has shown promising outcomes in osseointegration. Most surgical protocols include pre- and postoperative systemic AB and CHX rinses postoperatively. Even though the different treatment types cannot be compared, the expected outcome of surgical procedures to treat peri-implantitis is favorable.

**Surgical systematic review 3: Chala et al.**\textsuperscript{36} This SR included four RCTs observing the adjunctive use of lasers in the surgical treatment of peri-implantitis: Deppe et al,\textsuperscript{71} Papadopoulos et al,\textsuperscript{72} Schwarz et al,\textsuperscript{73} and Albaker et al.\textsuperscript{74}

Using the open-flap resective therapy, Papadopoulos et al found that both groups had the same clinical outcomes, with the laser offering no additional benefits 6 months after the procedure. Albaker et al found the same data in their study at the 6- and 12-month follow-ups. Deppe et al assessed CAL and the radiographic distance from implant shoulder to first bone contact (DIB). The data showed values from the 4-month and 5-year follow-ups. The only superior value found was the CAL in residual bone \((P < .05)\) at both follow-up checks. A significant difference was found at the 5-year mark for residual bone in terms of DIB.

As supported by Papadopoulos et al and Albaker et al, there was substantial evidence that the laser has no beneficial effect after 6 months. It is in partial consensus with Deppe et al, who failed to find statistically significant changes between groups after 4 months (except for the CAL). However, at the 5-year follow-up, they did see significantly better results for the test group.

For open-flap regenerative therapy in bone augmentation procedures, Deppe et al revealed that there was a statistically significant difference found only after 4 months. For DIB, a difference was also found for the augmented bone at the 4-month mark. They then concluded that the decontamination method played a secondary role 5 years after the treatment, which is in direct agreement with the result found by Schwarz et al,\textsuperscript{73} who also reported that, after 7 years, the outcome was not related to the method of decontamination of the implant surface.

To summarize, there is strong scientific evidence that corroborates that both treatments (mechanical debridement alone and mechanical debridement plus laser surface decontamination, followed by GBR) resulted in similar long-term outcomes.\textsuperscript{36}

To compare laser types, Papadopoulos et al used a diode laser and found no statistically significant difference between groups at the 3-month mark. Schwarz et al used an Er:YAG laser and failed to find any clear considerable benefit in usage after 6 months or 7 years. Therefore, it can be said there is strong scientific evidence that this type of laser (Er:YAG) had no significant benefits in terms of clinical outcomes.

For aPDT, Albaker et al disclosed no additional benefits after the 6- and 12-month follow-ups \((P > .05)\) in all clinical parameters. In this case, none of the results
were reviewable since Albaker et al provided no clinical measurements at 3 months.

**Surgical systematic review 4: Khan et al.** This SR included five RCTs that reported on surgical intervention for PI treatment, but two of them were already reported previously. Therefore, the following three studies are reported below: Hentenaar et al.75 de Waal et al.76 and Isehed et al.77

These three studies evaluated the following methods: (1) combination of resective surgery, (2) apically positioned flap, (3) bone recontouring, and (4) the usage of either saline solution/placebo or 0.12% CHX + 0.05% CPC solution. These studies tried to compare these treatment options alone versus with the addition of 35% phosphoric acid, 2% CHX solution, and enamel matrix derivative (EMD), respectively.

Hentenaar et al75 concluded that the adjunctive application of 35% phosphoric acid resulted in an immediate greater reduction of anaerobic bacterial load on the surface of the implant and significantly lowering the count of dental implants that were culture positive. Although this method showed successful decontamination of the implant surface, the phosphoric acid application did not show meaningful improvement in clinical measurements after the 3-month follow-up compared to the control group.

In 2015, de Waal et al76 investigated using 0.12% CHX + 0.05% CPC in group 2 while increasing the CHX to 2% in group 1 (test). This investigation failed to find significant differences in either microbiologic or clinical measurements between the two groups in a 12-month follow-up. The authors stated that 0.12% CHX + 0.05% CPC reduced the anaerobic load on the surface of the implant better than debridement alone. Nonetheless, this did not translate to improvements in clinical outcomes.

Isehed et al77 investigated regenerative surgical treatment to treat peri-implantitis with or without adjunctive EMD in a 5-year follow-up. No significant difference was found at baseline between groups in any parameters (BOP, SOP, and MBL). At the end of the 5 years, 4 out of 13 (31%) implants were lost or had to be treated again due to infection in the group with EMD, compared to 7 out of 12 (58%) in the group without EMD. The authors concluded that EMD treatment was associated with improved implant survival of up to 5 years. However, there were still no significant differences between the test and control groups.

Khan et al32 concluded their work by claiming that the field of PI treatment lacks the quality of study design/methodologic methods needed to make any assertive conclusion about the efficacy of any PI treatment.

**Surgical systematic review 5: Schwarz et al.** This SR included mostly RCTs already presented. To avoid bias and duplicate data, they were not reported again. However, the authors claimed that the studies available showed that resective surgery (apical repositioning of the flap + bone contouring) along with implantoplasty was more effective in achieving and maintaining disease resolution than resective surgery alone.

Augmentative surgical techniques of the intrabony defect component using porous titanium granules were linked to higher radiographic defect fill, even though they failed to improve BOP and PD. Clinical outcomes achieved with adjunctive augmentative procedures were superior to surgical measures alone. However, surgical procedures with and without soft tissue resection were grouped, and, due to that, interpretation of overall results was difficult. The results did not grant the statement of any potential superior protocol in augmentation therapies. Therefore, the authors of this SR33 concluded that surgical therapies, such as augmentative and resective techniques, along with adjunctive procedures, may have a beneficial clinical effect.

**Surgical systematic review 6: Kotsakis et al.** In this SR, the authors investigated the effect of different wavelengths (laser therapy) in the treatment of PI. Only two RCTs using surgical therapies were included. Both primary studies were already reported, but the effect of wavelength was not a variable in the previous study. Nonetheless, based on the information that was available, Kotsakis et al claimed that no superiority of laser treatment was found when compared to conventional therapy for PI. Due to the high heterogeneity and low number of studies included, the authors cautiously claimed that nonsurgical laser therapy might be appropriate and worth investigating as phase I therapy for PI.

**Surgical systematic review 7: Sanz-Sánchez et al.** This SR investigated the effect of lateral bone augmentation procedures on the implant and peri-implant health outcomes. The authors found that BOP was altered for all treatment options for lateral bone augmentation procedures. Still, the results were not statistically significant (test versus control group), and the RCT studies included had low heterogeneity. Therefore, no difference could be detected when comparing a group that used xenograft with native collagen membrane vs other types of membranes.

The addition of different biologic factors, such as bone morphogenetic protein (BMP) and platelet-derived growth factors (PDGF), also did not change the outcome significantly. The use of autogenous bone blocks along with a bioabsorbable collagen membrane showed similar results compared to using the bone block alone. This study’s meta-analysis evaluated the change in BOP values within each treatment option. There was no significant change for overall interventions as time went by. Using a cross-linked membrane plus a particulate xenograft revealed a statistically significant reduction in BOP values.
Data on PD showed no significant differences between test and control groups. Radiographic alterations in crestal bone levels were also not statistically different when comparing test and control groups.

Overall, assessing each treatment option independently, the meta-analysis from Sanz-Sánchez et al \(^{34}\) revealed that the interventions resulted in an overall lower value of BOP, although without any significant statistical difference among them. Evaluating other peri-implant aspects like MBL, PD, and plaque level, similar results were found among different surgical options, both for short- and long-term follow-ups.

**Surgical systematic review 8: Tomasi et al.** \(^{58}\) Tomasi et al included 16 studies, but only 3 included control groups and were designed as RCTs. Therefore, the remaining 13 studies were observational and were not included in the present work. These three RCTs were already reviewed above (Wohlfahrt et al., \(^{53}\) Isehed et al., \(^{78}\) and Jepsen et al. \(^{69}\)). Tomasi et al suggested that reconstructive surgical therapy for peri-implantitis is achievable, but it is also clear that the evidence is limited, and more studies are required.

The available evidence found in this review allowed the authors to claim that the low number of RCT studies limited the evidence level that reconstructive therapy could have in managing peri-implantitis defects. Also, the lack of RCT studies for the most commonly used procedures, the heterogeneity between studies, and the difference in selected outcome measures were factors that limited the investigation.

**Quality Assessment**

Utilizing the AMSTAR 2 rating tool \(^{30}\) (Appendix Table 4), four of the included SRs were considered to have high quality (Kotsakis et al., \(^{37}\) Schwarz et al., \(^{31}\) Tomasi et al., \(^{58}\) and Gao et al. \(^{38}\)), three with the moderate quality rate (Sanz-Sánchez et al., \(^{34}\) Aljohani et al., \(^{32}\) and Khan et al. \(^{33}\)), one of low quality (Chala et al.), and one of critically low quality (Mahato et al. \(^{35}\)).

**Tools applied for quality assessment/risk of bias within each SR.** The authors utilized different rating tools for the quality of assessment that was considered. Mahato et al. \(^{35}\) did not present a bias/quality table of studies included; the authors only mentioned that the inclusion of articles only in the English language could cause bias.

In the study of Chala et al. \(^{36}\), the authors claimed that, for quality assessment, a grade scale was applied based on some criteria, which were randomization and blindness, comparison of baseline status between groups (severity of the pathologic condition), description of protocol (treatment and irradiation), measurement of clinical parameters (baseline and follow-up), and radiographic evaluation (baseline and follow-up); final study classification was made regarding the number of positive answers to each individual criterion (four to five positive answers: high quality; two to three positive answers: medium quality; one positive answer: low quality). Moreover, the scientific evidence level was determined by study evaluation concerning the following criteria: strong evidence level, a conclusion confirmed by at least two investigations, contradictory scientific evidence, and a conclusion confirmed by studies in which findings are conflicting. After the quality assessment was made, all the included studies were considered to be high quality. All the studies scored five except for one, which scored four due to missing radiographic information. No bias information was available.

In the SR from Khan et al. \(^{33}\), the authors used the GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) tool to verify the quality of evidence for each treatment option. Concerning the risk of bias (ROB), the 2019 Cochrane Collaboration bias assessment tool was the chosen option to evaluate the included studies. The tool utilizes five main domains to assess each study as having low, concerning, or high ROB. Regarding the quality of evidence set by the GRADE tool, four of the publications were considered low-quality evidence, and the other nine were supposed to be of very low quality. Due to this fact, the real effect of interventions is most likely to be considerably removed from the approximate effect of most interventions.

Schwarz et al. \(^{31}\) in their SR, presented a table in which they assessed the ROB from the selected randomized studies utilizing the Cochrane Collaboration tool. A qualitative assessment was made independently by both authors of the study in phase I, mainly through the published full-text article. In phase II, disagreements were resolved by discussion between authors.

In the SR of Kotsakis et al. \(^{37}\) authors utilized the revised CONSORT (Consolidated Standards of Reporting Trials) tool to evaluate the RCTs. A supplementary table was reported to exist online with this data but could not be found online for confirmation. Regarding the ROB, three studies were considered to be of high risk of bias (Schwarz et al., 2005 \(^{55}\); Schwarz et al., 2006 \(^{62}\); and Deppe et al., 2007 \(^{71}\)), one moderate risk of bias (Schär et al., 2013 \(^{46}\)), and two low risks of bias (Renvert et al., 2011 \(^{43}\) and Schwarz et al., 2012 \(^{59}\)).

Gao et al. (2020) \(^{38}\) utilized the GRADE assessment tool to evaluate the quality of evidence provided by the included articles. The Cochrane Collaboration ROB tool was used to assess this parameter. The studies included in this SR were only two, Galofré et al. (2018) \(^{36}\) and Tada et al. (2018) \(^{57}\) as the others were concerned with peri-implant mucositis and not PI. Both studies were classified as having a low risk of bias. GRADE assessment revealed a moderate quality of evidence from both studies.
The SR of Sanz-Sánchez et al (2017) reported that the quality of the included RCTs was reviewed by one of the authors, utilizing the Cochrane Collaboration recommendations. Each of the following criteria was assessed as low, high, or unclear ROB: (1) selection bias (sequence generation and allocation concealment); (2) performance bias (blinding of participants/researchers); (3) detection bias (blinding of outcome assessment); (4) attrition bias (incomplete data report); (5) selective report bias (report of selective outcomes); (6) other potential ROB. The RCTs of Jung et al (2017) and Schwarz et al (2014, 2016) reported a low ROB in all criteria. The study from Jung et al (2015) also had a low ROB score in all parameters except for one.

Tomasi et al (2019) mentioned that regarding the ROB of individual studies, within the included RCTs, only one (Isehed et al, 2016) was rated as having a low ROB. The authors of the SR claimed that the difficulty was in blinding the examiner during radiographic assessment to evaluate grafts for bone replacement (detection bias). As it concerns publication bias, findings were nonsignificant in reduction of MBL and PD for the three RCTs.

**DISCUSSION**

**Nonsurgical Treatment**

Six SRs included NS approaches to treat PI. Mahato et al claimed that although NS treatment could significantly improve clinical parameters, the bacteria responsible for the pathogenesis are not decreased. This claim was confirmed in other studies.

Chala et al reported that none of the included RCTs regarding NS treatment and adjunctive laser application could show complete resolution of the local inflammation. The available literature supports that incomplete bacterial removal is an open door to the progression of PI.

The lasers and respective wavelengths in the included RCTs were as follows: diode laser (DL) 670 nm (in aPDT), Nd:YAG 1064 nm, and Er:YAG 2940 nm. The DL intervention groups presented equally efficient improvement across clinical parameters, reducing mucosal inflammation compared to control, but showed a higher MBL. The benefits from the PDT with DL were significant up to 6 months post-intervention, but at the 6-month follow-up, the improvement was significantly reduced, meaning that the laser application made tissue healing happen faster than with MD alone.

The authors, referencing another SR, stated that the use of laser during an NS approach should be investigated as a previous intervention for posterior surgical treatment. The SR from Chala et al stated that, based on the included RCT, NS intervention could efficiently control the inflammation of peri-implant tissue for 6 months. Also, in their SR, Kotsakis et al had four NS RCTs investigating the effects of various laser wavelengths on PI treatment. The authors claimed that NS treatments with adjunctive laser tools showed reduced attachment loss and PD. Both were decreases of < 1 mm.

The most recent American Academy of Periodontology (AAP) best evidence consensus of laser therapy for PI treatment in 2018 revealed similar data to the two previously cited SRs. The authors stated that among their evaluated studies, the SR and meta-analyses they performed did not identify significant PD lowering nor CAL gain when combining lasers with NS techniques.

These findings are similar to another AAP consensus from Chambrone et al regarding the use of PDT, which also utilizes low-wavelength lasers; eg, DL. DL showed promising results in two recent reviews regarding PD reduction and CAL gain, but further, better-designed investigations should be planned.

Concerning BOP, the 2018 laser consensus from AAP reported conflicting results, as some studies stated that a significant reduction was achieved when lasers were used instead of regular MD. Still, other studies failed to find significant data. Even those that found a positive effect on reducing BOP levels showed a limited time-frame effect (6 months).

The meta-analysis from Lin et al exhibited data that corroborated no added benefits in PlqI reduction when lasers were applied as an adjunctive measure to regular MD. From the current evidence found in the two previous SRs with RCTs and the most recent AAP consensus, laser as an adjunctive tool for the NS treatment of PI has limited benefits. Only Er:YAG, CO₂, and DL could be analyzed with the current evidence, as studies for other laser types did not use a control group to support the evaluations made.

With that being said, further RCTs should be elaborated to clarify the role adjunctive laser application can have in NS PI treatment. Khan et al, investigating the management of PI lesions without systemic AB associated with NS options, found a lack of high-quality clinical trials in the studied area. All interventions assessed by the authors were of either low or very low quality.
of evidence, putting in jeopardy the actual effect of the interventions versus the estimated effect.\textsuperscript{33}

Concerning NS options, the adjunctive use of chloramine gel as a detoxification measure had the same effect as NS MD alone. However, both showed significant improvement in clinical parameters for a 3-month follow-up. Due to a short follow-up period and only 18 people included in the study, the results need to be cautiously interpreted.\textsuperscript{33}

In the investigation of MatrixC and PerioC chip application following NS treatment, the PerioC group revealed a more significant PD reduction (2.19 mm) versus MatrixC (1.59 mm), as well as a more significant CAL gain (2.21 versus 1.56 mm).\textsuperscript{33} However, no differences in BOP were noted between groups at the 6-month follow-up. The SR authors considered this RCT well conducted, and its positive results suggest further investigation.

Air-abrasive device versus manual MD and local CHX application showed similar results. Both revealed PD reduction and CAL gains, but air abrasion with glycine powder had a greater BOP reduction power.\textsuperscript{33} Suggestions were made about NS therapy’s efficacy and the adjunctive aid of an air-abrasive device concerning a threshold effect level. As both studies that investigated this combination of treatments had methodologic concerns and a high ROB, results have to be interpreted with caution.

The conclusion reached in the SR from Schwarz et al was that the found weighted mean difference in BOP scores favored adjunctive AB therapy, applied locally, or alternative debridement methods, such as laser application or abrasive air polishing with glycine over the control measure applied in most RCTs. PD scores did not show the same improvements using conventional debridement methods or adjunctive/alternative approaches, such as air-abrasive polishing, PDT, antiseptic CHX chips, AB, and lasers.\textsuperscript{31} The authors also claimed that the deeper the PD is at a site, the more limited the efficacy. Several studies found increased BOP between 3- and 12-month follow-up after NS intervention in those severe cases. Treatment efficiency was higher in moderately deep sites. Nonetheless, investigators caution that PD scores can be influenced by several other factors, including implant positioning, implant-abutment connection, occlusal load, and soft tissue thickness.\textsuperscript{31}

Regarding the adjunctive effect of \textit{Lactobacillus} probiotic with NS measures (supragingival scaling with ultrasonic carbon fiber tips and titanium curettes), one study showed significantly improved BOP and PD at the implant level, post-intervention, in the probiotic group.\textsuperscript{38} The other study encountered a significant PD decrease after probiotic application, but BOP was not significantly different between the test and control groups. Although this probiotic field is not new in oral health care,\textsuperscript{89} it is an adjunctive measure in the NS treatment of PI. More studies are still required to prove significant differences regarding applying probiotic single strains or mixes.\textsuperscript{38,89}

As for the NS therapeutic options for treating PI reported above, most findings were confirmed in a recent consensus report made by Renvert et al.\textsuperscript{84} The authors of this consensus report concluded that air-abrasive polishing devices, Er:YAG lasers, and manual or ultrasonic curettes can be used to treat PI. Most of the aforementioned treatments showed some degree of clinical improvement, eg, reduced BOP, and, in a few cases, PD reduction of measurements of 1 mm or less. NS treatment for complete disease resolution is most likely not enough in more severe cases.\textsuperscript{11,84}

\section*{Surgical Treatment}

\textbf{Regenerative approaches.} Aljohani et al gathered data from RCTs that evaluated the efficacy of regenerative surgical treatments for PI.\textsuperscript{32} The authors claimed that all the studies revealed improvements in clinical parameters compared to baseline. Nonetheless, all studies failed to prove any statistical significance based on their different surgical approaches regarding PD, BOP, RBL, and vestibular margin recession.\textsuperscript{32}

The highest PD reduction was reported in studies that utilized bone substitutes (bovine-derived xenograft and porous titanium granules). The authors suggested that bone substitute materials may be better in improving PD versus other non-regenerative surgical treatments.\textsuperscript{32} Regarding BOP, no RCT showed superiority between the different techniques used, even though they were significantly improved. RBL was another investigated parameter, and studies that utilized bone substitutes had increased RBL compared to base levels. No study could affirm that the chosen technique was more predictable than the others. The highest bony defect fill was accomplished with porous titanium granule usage, bovine xenograft, and autogenous bone.\textsuperscript{32}

One of the included studies by Aljohani et al had a 48- and 84-month follow-up regarding two different methods for surface debridement and other detoxification methods in the surgical treatment of PI. After access flap surgery, removal of inflammatory tissue, and implantoplasty in both groups, the first one was treated with Er:YAG laser, and the second one received MD with plastic curettes, cotton pellets, and saline (sterile). After detoxification and cleaning, both groups received natural bone minerals and a collagen membrane. No statistical difference was found between the two groups at both checkups mentioned previously. It was ultimately concluded that the different methods of decontamination\textsuperscript{32,73} did not influence the treatment outcome.
Aljohani concluded their work by stating that, within the limitations of the included RCTs, porous titanium granules had the best effect on bone defect filling (with radiographic confirmation). The better PD results were with the bovine-derived xenograft. Defect shape also influences this predicted filling.\textsuperscript{32} No clear advantage was shown to support the use of Er:YAG laser, a submerged implant technique, or membranes. Other well-designed RCT studies with long-term follow-ups and large sample sizes are required to make better conclusions.

Chala et al, in their SR, had similar findings to Aljohani et al in terms of regenerative approaches; there is not enough evidence to recommend a specific surgical regenerative technique or material to be used. It was also suggested that the means of detoxification have a minor role in the treatment outcome.\textsuperscript{36}

Data from an RCT from the SR of Khan et al corroborated that EMD was associated with implant success (survival).\textsuperscript{33} The follow-up period was 5 years, and the authors anticipated that EMD could have a prompt healing and antimicrobial effect. Despite the long follow-up, the cited RCT had a high ROB, and the sample was a small size, so the quality of this evidence is very low.

Data from the most recent consensus report on the surgical treatment of PI\textsuperscript{48} confirmed the findings from Aljohani et al and Chala et al. Although surgical augmentative/regenerative technique procedures result in better clinical and radiographic outcomes for treating PI, there is no concrete evidence to support the specific use of a single material, membrane, or product.

Regarding the decontamination process, Khoury et al and Koo et al also failed to detect any significant effect of a certain decontamination method,\textsuperscript{80,91} supporting the previous finding from Schwarz et al.\textsuperscript{73}

The SR from Mahato et al\textsuperscript{35} had the lowest quality assessment among the included SRs. This was because no quality assessment was made available in the study of the included RCTs. Also, no ROB was evaluated. As such, the conclusions reached by the authors might not be the most accurate of scientifically proven data. Mahato et al claimed that their study found that disease resolution is satisfactory with surgical treatment. The authors also claimed that if the bony defect is small, implantoplasty can improve the defect. Moreover, GBR or application of a bone substitute can be an effective treatment for PI.\textsuperscript{33} This is an overly simplified affirmation that cannot be made with certainty, as the effectiveness of the surgical procedure can be variable, and literature to support its predictability and long-term success is scarce.\textsuperscript{90,91}

The SR from Schwarz et al found similar study findings to the ones that have been reported so far, further supporting that surgical augmentative/regenerative techniques are helpful and can lead to better clinical outcomes than NS techniques. Still, no clear “gold standard” for technique nor materials are reported. Submerged implant healing seems to have better overall results than non-submerged healing.\textsuperscript{31}

The SR from Kotsakis et al included only two studies that concerned surgical treatment of PI. The outcome was that, compared to nonsurgical approaches, surgical interventions reduced the clinical parameters at least twice as much, therefore obtaining improved treatment outcomes.\textsuperscript{37} The authors stated that this conclusion is in line with other reviews about PI treatment and outcomes; a consensus was established that NS interventions have a limited range of effects, so surgical interventions are starting to be the “go-to” procedures.

The results from the SR of Sanz-Sánchez et al revealed that lateral bone augmentation interventions and various bony replacements and different membranes could maintain steady results over time when it comes to reducing inflammation of the mucosa and keeping bone levels unaltered.\textsuperscript{34} Evaluating each treatment technique by itself, no significant BOP, bone margin level, PD, or PI change was found. These results were for short (3 months to 3 years) and long (5 years or more) follow-ups.

Overall, data and information from the included SRs and the most recent consensus reached the same conclusion regarding regenerative/augmentative techniques: Improvements in clinical parameters are likely to happen and outcomes are expected to improve post-intervention, but by how much is not an easy parameter to estimate. Also, no technique or material has shown clear superiority over another.

Resective approaches. In the SR from Chala et al, regarding resective approaches, the authors reported that in most of the included studies where a resective technique was used, a full-mouth MD was first realized to maximize the reduction of bacterial count.\textsuperscript{35} The SR also stated that findings among studies utilizing resective techniques are expected to present contrasting results. Many of the factors that directly impact the outcome are not yet fully understood (ie, etiology, pathogenesis, surgical procedure, and expertise).

All surgical resective techniques aimed to cease exacerbated inflammatory response in the tissue responsible for PI development. Soft tissue margin also must be kept around the implants’ coronal platform.\textsuperscript{36}

DL’s use for implant decontamination and soft tissue resection showed significant improvement in CAL and PD in two of the included studies. Nonetheless, considering the study design and evaluation by the SR authors, this is not strong enough evidence to fully prove the benefit of laser versus conventional debridement in combination with resective surgery.\textsuperscript{36}

Khan et al, in their SR, found data from RCTs that evaluated resective procedures and some different
adjunctive measures. The use of 35% phosphoric acid was combined with a resective intervention and detoxification with saline. Greater repression of anaerobic bacteria was identified at the implant surface in the test group; nevertheless, no improved clinical outcomes were detected along with that reduced load of anaerobic bacteria at the 3-month follow-up. A hypothesis suggested by the authors theorizes that, although low-pH acids have reported bactericidal effects and no sequelae on the titanium implant surface, acidic solutions might hinder new osseointegration.

Also, concerning detoxification methods simultaneously used with resective surgical interventions, RCTs investigated a 0.12% CHX + 0.05% CPC solution, which revealed a significant bacterial load reduction on the implant surface, but as previously cited, the study failed to find significant results at a 12-month follow-up. The same study was later replicated, comparing 0.12% CHX + 0.05% CPC versus 2% CHX. No significant differences were found between the applied solutions, although both showed effectiveness in improving clinical and microbiologic outcomes (at 3-, 6-, and 12-month follow-ups).

The adjunctive use of DL in the surgical resective treatment improved CAL significantly, but no other positive outcome was registered over surgical resective treatment alone. As no other clinical parameters were improved, the benefits from DL adjunctive use were considered limited; this included RCT had a high ROB and reduced sample sizes and was considered by the authors of the SR to be of very low quality. This meant that active PI was present or progressing at the 3-month follow-up, this in agreement with the findings from the SRs mentioned previously.

The consensus from Khoury et al also corroborates these findings, concluding that clinical parameters are improved when surgical resective techniques are conducted most of the time. Still, clear benefits are yet to be reported regarding systemic AB use. The group 4 FDI consensus report also stated significant improvements, especially in studies that utilized adjunctive implantoplasty with diamond or Arkansas burs and silicone polisher. Concerns still revolve around implantoplasty, as titanium particles might linger inside the oral cavity and be hazardous to patients’ health. This surgical technique might have another downside, as there are concerns about the consequences of altering the implants’ surface, mainly in terms of how it affects its structural integrity; it might compromise load distribution, and implant fracture might have a greater tendency to occur. More studies are needed to understand the effects of implantoplasty fully, but the controversy stands as of now.

CONCLUSIONS

Within the limitations of this umbrella review, the following conclusions can be made.

NS interventions for treating PI have limited effects and are, most likely, not enough to stop PI development nor to resolve it. NS options can improve clinical parameters like BOP and PD to a lesser degree but are recommended in the initial stages of the disease, or for a more effective action, to treat peri-implant mucositis and stop the evolution to fully established PI. The greater the PD, the more limited the effect of the NS approach seems to be.

NS interventions with alternative/adjunctive methods, using lasers and local AB/antiseptic therapy, may tend toward better clinical results/outcomes, although some results remain controversial.

Er:YAG laser, air-abrasive polishing with glycone powder, MD with curets or ultrasonic devices, and local AB/antiseptic measures have slightly better clinical results when used in conjunction with NS approaches. None of these techniques significantly reduced the bacterial load on the implant surface. The ones that did only reduced the amount of pathogenic bacteria present for 6 months, at most.

NS therapies seem to be insufficient to treat PI successfully; therefore, the more appropriate option appears to be a surgical approach that can either be regenerative/augmentative or resective.

Findings for regenerative/augmentative techniques seemed to be generally positive, as they display better clinical and radiographic outcomes in the investigated
studies. Predicting the grade of improvement with the surgical intervention is hard to do.

As for the materials used in this type of approach, no clear superiority was demonstrated. Autogenous bone remains the “gold standard,” but sometimes resorption of the material can happen more quickly, and the regenerative process can fail. The generally better results in PD improvement and radiographic bony fill were obtained with bovine-derived xenograft and porous titanium granules. Submerged implant healing seemed related to better clinical improvements.

When it comes to the method for implant surface detoxification within surgical therapies, no technique has been revealed to be superior to another.

In regenerative surgical techniques, clinical parameters are also improved most of the time, but a clear benefit from the use of AB is still to be fully reported.

Implantoplasty seemed to demonstrate significant improvements in clinical parameters in surgical interventions for the treatment of PI. This procedure can be done with diamond or Arkansas burs, along with siliccone polishers.

Some concerns still arise from implantoplasty execution, such as lingering titanium particles in the oral cone polishers.

RCTs that are more adequately designed and with larger samples need to be planned to find a definitive answer to the proposed question. Establishing a defined standard for PI diagnosis to be utilized across all PI investigation studies would also help even the field and facilitate comparison of interventions.

ACKNOWLEDGMENTS

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REFERENCES


68. The International Journal of Oral & Maxillofacial Implants 675

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# APPENDIX

## Appendix Table 1  Search Terms Following the PICO Strategy

| P | Peri-implantitis, OR Perimplantitis, OR Peri-implant disease, OR Peri-implant disease, OR Defect, OR Implant, OR Dental implant; AND |
| I | Treatment, OR Peri-implantitis therapy, OR Adjunctive therapies, OR Chlorhexidine, OR Antibiotic, OR Laser; AND Nonsurgical; AND |
| C | Surgical, OR Surgery, OR Implantoplasty, OR Peri-implantitis therapy, OR Graft, OR Debridement, OR Supportive, OR Laser, OR Resective Surgery, OR Membrane, OR Surgical regenerative therapy, OR Bone substitute, OR Regeneration, OR Collagen; AND |
| O | Survival rate, OR Success rate, OR Implant failure rate, OR Marginal bone loss (MBL), OR Bleeding on probing (BOP), OR Probing pocket depth (PPD), OR Probing depth (PD), OR Probing in-depth (PD), OR Clinical attachment level (CAL). |

## Appendix Table 2  AMSTAR 2 with 16 Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tr>
<td>1. Did the research questions and inclusion criteria for the review include the components of PICO?</td>
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<tr>
<td>2. Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?</td>
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<td>3. Did the review authors explain their selection of the study designs for inclusion in the review?</td>
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<td>4. Did the review authors use a comprehensive literature search strategy?</td>
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<td>5. Did the review authors perform study selection in duplicate?</td>
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<td>6. Did the review authors perform data extraction in duplicate?</td>
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<td>7. Did the review authors provide a list of excluded studies and justify the exclusions?</td>
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<td>8. Did the review authors describe the included studies in adequate detail?</td>
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<td>9. Did the review authors use a satisfactory technique for assessing the risk of bias (ROB) in individual studies that were included in the review?</td>
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<td>10. Did the review authors report on the sources of funding for the studies included in the review?</td>
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<td>11. If meta-analysis was performed, did the review authors use appropriate methods for statistical combination of results?</td>
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<td>12. If meta-analysis was performed, did the review authors assess the potential impact of ROB in individual studies on the results of the meta-analysis or other evidence synthesis?</td>
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<td>13. Did the review authors account for ROB in individual studies when interpreting/discussing the results of the review?</td>
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<td>14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?</td>
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<td>15. If they performed quantitative synthesis, did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?</td>
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<td>16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?</td>
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<td>Study Authors and Year</td>
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**Appendix Table 3: Systematic Reviews and Primary Studies Included**

PS = primary study. Some primary studies included in the systematic reviews are not included in the reference list of the present article.
<table>
<thead>
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<th>Studies</th>
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Y = yes; PY = partial yes; N = no; O = not applicable.
*See Appendix Table 2 for AMSTAR 2 criteria questions.*