With the increasing attention on peri-implant diseases and conditions, plaque-induced inflammation around implants has been regarded as one of the most important etiologic factors. In spite of various definitions of clinical characteristics for peri-implantitis, deepening probing depth (PD) correlated with progressive marginal bone loss (MBL), clinical attachment level (CAL), and mucosal recession (REC) at baseline and follow-ups were extracted from original articles for qualitative analyses. Risk ratio and weighted mean difference with 95% CI were calculated using a random-effects model. Results: Out of 322 studies, 17 (9 randomized controlled trials, 4 controlled clinical trials, and 4 case series) were included in the present study. The regeneration group presented a 97% (95% CI: 0.95 to 1.00) implant survival rate, and the nonregeneration group showed a 94% (95% CI: 0.90 to 0.98) survival rate. Both groups revealed similar outcomes in PD and BOP reductions and soft tissue REC. However, the regeneration group had more favorable results in MBL. Conclusion: Data from this study suggested that applying implantoplasty during a regeneration or nonregeneration surgical approach resulted in a high implant survival rate and peri-implantitis resolution. Although no differences were found in the majority of clinical parameters in both groups, the regenerative approach resulted in more radiographic bone fill than the nonregenerative treatment. Int J Oral Maxillofac Implants 2022;37:859–868. doi: 10.11607/jomi.9436

Keywords: implantoplasty, peri-implantitis, regeneration, surgical treatment, systematic review

The Impact of Implantoplasty in Regenerated and Nonregenerated Treatment Modalities in Peri-implantitis: A Systematic Review and Meta-analysis

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Whei-Lin Pan, DDS1/Hom-Lay Wang, DDS, MS, PhD2

Purpose: To investigate the impact of implantoplasty (IP) with or without regenerative procedures on treatment outcomes of peri-implantitis. Materials and Methods: Electronic and manual literature searches were conducted for clinical trials published up to October 2020 that evaluated clinical outcomes (at least 6-month follow-up) after peri-implantitis treatment involving IP. The implant survival rate and clinical parameters (eg, probing depth [PD], bleeding on probing [BOP], marginal bone loss [MBL], clinical attachment level [CAL], and mucosal recession [REC]) at baseline and follow-ups were extracted from original articles for qualitative analyses. Risk ratio and weighted mean difference with 95% CI were calculated using a random-effects model. Results: Out of 322 studies, 17 (9 randomized controlled trials, 4 controlled clinical trials, and 4 case series) were included in the present study. The regeneration group presented a 97% (95% CI: 0.95 to 1.00) implant survival rate, and the nonregeneration group showed a 94% (95% CI: 0.90 to 0.98) survival rate. Both groups revealed similar outcomes in PD and BOP reductions and soft tissue REC. However, the regeneration group had more favorable results in MBL. Conclusion: Data from this study suggested that applying implantoplasty during a regeneration or nonregeneration surgical approach resulted in a high implant survival rate and peri-implantitis resolution. Although no differences were found in the majority of clinical parameters in both groups, the regenerative approach resulted in more radiographic bone fill than the nonregenerative treatment. Int J Oral Maxillofac Implants 2022;37:859–868. doi: 10.11607/jomi.9436

Keywords: implantoplasty, peri-implantitis, regeneration, surgical treatment, systematic review
the implant survival rate, and the secondary outcome was to examine the clinical parameters and assess the factors that may influence the treatment outcome.

**MATERIALS AND METHODS**

This systematic review and meta-analysis was reported and conducted in accordance with the 27-item Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The focus question was: What are the impacts of IP on peri-implantitis treatment using either nonregenerative (eg, open flap debridement) or regenerative (eg, guided bone regeneration) surgical intervention? This statement was elaborated using the Population, Intervention, Comparison, and Outcome (PICO) criteria:

- **P**: Subjects with one or more implants diagnosed as peri-implantitis.
- **I**: Implants with peri-implantitis that have undergone IP during surgical treatment (regenerated and nonregenerated approach).
- **C**: The differences in peri-implant conditions at baseline and follow-up in terms of implant survival and other clinical parameters between regenerated and nonregenerated treatment were assessed and evaluated.
- **O**: The primary outcome of this meta-analysis was the survival rate of the diseased implants, and secondary outcomes considered the difference in all clinical parameters (PD, BOP, MBL, clinical attachment level [CAL], and mucosal recession [REC]).

**Selection Criteria**

Eligible studies that met the following criteria were included: (1) the studies comprised more than five cases utilizing IP with either regenerated or nonregenerated surgical approaches in any clinical studies, including prospective or retrospective randomized or controlled clinical trials; (2) at least a 6-month follow-up period after surgical treatment; and (3) data of peri-implant conditions (either survival rate, PD, BOP, MBL, defect fill, or REC) were required for assessment. Exclusion criteria were as follows: (1) animal studies; (2) studies including patients with heavy smokers, diabetes mellitus, noncontrolled systemic disease, noncontrolled periodontal disease, or immunocompromised; and (3) reviews.

**Search Strategy**

The search strategy was mainly conducted by means of three electronic databases—PubMed/MEDLINE, EMBASE, and Cochrane Central—for articles published up to October 2020. The search terms used for collecting articles were: (periimplantitis OR peri-implantitis OR peri-implant disease) AND (implantoplasty OR implant surface decontamination OR implant surface modification OR implant surface detoxification)


Two independent reviewers (C.L. and Z.C.) screened all the articles derived from the search process. According to selection criteria, titles and abstracts of search results were evaluated, and then potential articles were assessed in full text. To assess the level of interreviewer agreement for study inclusion, the kappa value was also calculated. Consultation and thorough discussion with a senior reviewer (H.L.W.) was done if there was a disagreement on selected studies.

**Risk of Bias Assessment**

All selected RCTs were assessed by the Cochrane Collaboration checklist, including random sequence generation, allocation concealment, blinding of outcome assessment, incomplete outcome data, selected reporting, and other bias. If all criteria were met, degree of bias was categorized as low risk. Those missing more than two criteria were rated as high risk, and those missing two or fewer criteria were considered as moderate risk. Meanwhile, the included cohort studies were assessed using the Newcastle-Ottawa scale, and each article was rated from 0 to 8 stars for each parameter in the scale.

**Data Extraction and Statistical Analyses**

The data were extracted from the eligible articles by two independent reviewers (C.L. and Z.C.). Any interreviewer disagreement was resolved by discussion and consultation with another reviewer (H.L.W.). Corresponding authors of potential studies were contacted in cases of missing or unclear data.
All statistical analyses were conducted using one statistical software program (Stata software, version 14.0, StataCorp). The cumulative survival rate of diseased implants (at the implant level) with 95% CI was calculated using a random-effects model to avoid potential bias due to methodologic differences among selected studies. Data of clinical parameters (eg, PD, MBL, CAL, and REC) were analyzed with a random-effects model to compare the influence of IP on baseline and follow-up conditions. Heterogeneity was estimated using the Q statistic (significant at $P < .1$) and quantified with the $I^2$ test. A value of $I^2 \geq 75\%$ suggests high heterogeneity.

RESULTS

Study Selection
Figure 1 illustrates the experimental flowchart of the screening process. Electronic and manual searching in PubMed and other databases yielded 341 potential articles, and 19 duplicates were removed; hence, 322 studies remained. After title and abstract screening, 302 studies identified as irrelevant articles, reviews, or animal studies were all excluded. A total of 20 articles were evaluated with full-text screening, and $3^{18-20}$ were ruled out with reasons (Table 1). Eventually, there were 17 studies included for further evaluation. Among all included articles, 8 were IP with nonregenerative treatment and 9 were IP with regenerative treatment. Additionally, the kappa value was 0.92 for interreviewer agreement between the two reviewers.

Description of Studies
All included articles are summarized in Table 2. Based on the surgical approaches, all studies were divided into two groups: (1) regeneration procedure with IP (Table 2a) and (2) nonregeneration approach with IP (Table 2b). Extracted data were comprehensively evaluated with respect to different characteristics, including follow-up time, location of IP, additional chemical agent, adjunctive laser application, grafted materials in regeneration, and interval of maintenance (Table 2c).

In group 1, regeneration with IP, nine articles were included for further assessment, among which five were RCTs, two were case series, and one was a retrospective cohort study. The same group conducted a long-term observation of surgical treatment performed in peri-implantitis lesions using two different surface debridement and decontamination methods: plastic curettes and cotton pellets with normal saline or erbium-doped yttrium aluminum garnet (Er:YAG) laser device. Although similar clinical outcomes were achieved in both groups, some concerns, such as limited sample size, different implant systems, large variations in parameters, and diverse defect configurations, remain to be considered when interpreting the results. To be more specific, the group with laser application revealed a more severe supracrestal defect, which might impact the outcomes. Different defect sizes were included in related articles: One study only treated moderate depth of bony destruction ($\leq 2.5$ mm), and one managed more severe defect with 4 mm in depth, 2.6 mm in width, and 4.6 mm above the bone level. In addition, different regenerative materials, which may also influence the outcomes, were used, including allograft with collagen membrane, allograft with alloglomer, xenograft with collagen membrane, and a combination with additional soft tissue graft. To enhance the impact of decontamination, one study performed irrigation with hydrogen peroxide and a mixture of the graft with local antibiotics, and six studies utilized an Er:YAG laser device as the adjunctive treatment for debridement.

Regarding the maintenance strategy after surgery, five studies adopted monthly cleaning for the first 6 months, and each one of the remaining articles saw patients every 2 months, every
### Table 2a Implantoplasty (IP)+ Augmentative Treatment

<table>
<thead>
<tr>
<th>Study/year</th>
<th>Follow-up time</th>
<th>Study type</th>
<th>Pt/Imp</th>
<th>Defect type (depth, width) (mm)</th>
<th>Implantoplasty</th>
<th>Location</th>
<th>Other methods</th>
<th>Regeneration</th>
<th>PDO (mm)</th>
<th>BOPO (%)</th>
<th>CAL (mm)</th>
<th>RECO (mm)</th>
<th>SPT</th>
<th>Failed implant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schwarz et al-1 (2011)</td>
<td>6 mo</td>
<td>RCT</td>
<td>15/19</td>
<td>Ibc+II</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>ERL(2940)</td>
<td>Bio-Oss + Bio-Gide</td>
<td>5.1</td>
<td>(1.6)</td>
<td>93.3</td>
<td>(18.7)</td>
<td>6.4</td>
<td>(2)</td>
</tr>
<tr>
<td>Schwarz et al-2 (2011)</td>
<td>6 mo</td>
<td>RCT</td>
<td>15/16</td>
<td>Ibc+II</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>CPS</td>
<td>Bio-Oss + Bio-Gide</td>
<td>5.5</td>
<td>(1.8)</td>
<td>100</td>
<td>(0)</td>
<td>6.7</td>
<td>(2.2)</td>
</tr>
<tr>
<td>Schwarz et al-1 (2012)</td>
<td>2 y</td>
<td>RCT</td>
<td>14/14</td>
<td>Ibc+II</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>ERL(2940)</td>
<td>Bio-Oss + Bio-Gide</td>
<td>4.9</td>
<td>(1.4)</td>
<td>96.6</td>
<td>(10.6)</td>
<td>6.4</td>
<td>(2)</td>
</tr>
<tr>
<td>Schwarz et al-2 (2012)</td>
<td>2 y</td>
<td>RCT</td>
<td>10/20</td>
<td>Ibc+II</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>CPS</td>
<td>Bio-Oss+BioGuide</td>
<td>5.2</td>
<td>(1.5)</td>
<td>100</td>
<td>(0)</td>
<td>6.5</td>
<td>(2)</td>
</tr>
<tr>
<td>Schwarz et al-1 (2013)</td>
<td>4 y</td>
<td>RCT</td>
<td>7/9</td>
<td>Ibc(2.2)+II(2.5)</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>ERL(2940)</td>
<td>Bio-Oss+Bio-Gide</td>
<td>5.1</td>
<td>(1.5)</td>
<td>95.2</td>
<td>(12.6)</td>
<td>7.3</td>
<td>(1.9)</td>
</tr>
<tr>
<td>Schwarz et al-2 (2013)</td>
<td>4 y</td>
<td>RCT</td>
<td>10/12</td>
<td>Ibc(2.5)+II(2.4)</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>CPS</td>
<td>Bio-Oss+BiGide</td>
<td>5.5</td>
<td>(1.7)</td>
<td>100</td>
<td>(0)</td>
<td>6.7</td>
<td>(1.8)</td>
</tr>
<tr>
<td>Schwarz et al-1 (2017)</td>
<td>7 y</td>
<td>RCT</td>
<td>6/6</td>
<td>Ibc(2.35)+II(3.04)</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>ERL(2940)</td>
<td>Bio-Oss+Bio-Gide</td>
<td>4.78</td>
<td>(1.45)</td>
<td>93.32</td>
<td>(14.93)</td>
<td>6.78</td>
<td>(2.02)</td>
</tr>
<tr>
<td>Matarasso et al (2014)</td>
<td>6 mo</td>
<td>series</td>
<td>10/13</td>
<td>Ibc(2.4)+II(2.6)</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>CPS</td>
<td>SCTG + Bio-Oss + Bio-Gide</td>
<td>6.15</td>
<td>(0.8)</td>
<td>92.3</td>
<td>(16.12)</td>
<td>6.69</td>
<td>(0.94)</td>
</tr>
<tr>
<td>Nart et al (2018)</td>
<td>1 y</td>
<td>series</td>
<td>11/11</td>
<td>Intra(4), supra(4.6), wid: 2.6</td>
<td>Stainless cu+diamente+stone + polisher</td>
<td>B+supra</td>
<td>Airflow</td>
<td>Supra</td>
<td>Ultrasonic + H2O2</td>
<td>8.1</td>
<td>(1.8)</td>
<td>19.7</td>
<td>(40.1)</td>
<td>9.7</td>
</tr>
<tr>
<td>Ramanauskaite et al-1 (2018)</td>
<td>41 mo</td>
<td>RETRO (non-grated site)</td>
<td>10/16</td>
<td>Combined (No detail)</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>ERL or CPS</td>
<td>Bio-Oss+Bio-Gide</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2 mo</td>
<td>SPT</td>
</tr>
<tr>
<td>Ramanauskaite et al-2 (2018)</td>
<td>41 mo</td>
<td>RETRO (grated site)</td>
<td>29/41</td>
<td>Combined (No detail)</td>
<td>Plastic cu+diamente+stone</td>
<td>B+supra</td>
<td>ERL or CPS</td>
<td>Bio-Oss+Bio-Gide</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>6 mo</td>
<td>SPT</td>
</tr>
<tr>
<td>Wang et al-1 (2020)</td>
<td>6 mo</td>
<td>RCT</td>
<td>12/12</td>
<td>Ion-IIC</td>
<td>No detail</td>
<td>Supra</td>
<td>Scaler + ERL</td>
<td>Allograft + ADM</td>
<td>7.73</td>
<td>(1.95)</td>
<td>83</td>
<td>(30)</td>
<td>7.43</td>
<td>(1.91)</td>
</tr>
<tr>
<td>Wang et al-2 (2020)</td>
<td>6 mo</td>
<td>RCT</td>
<td>12/12</td>
<td>Ion-IIC</td>
<td>No detail</td>
<td>Supra</td>
<td>Piezoelectric &amp; stainless steel scalers.</td>
<td>Allograft + ADM</td>
<td>6.44</td>
<td>(1.07)</td>
<td>86</td>
<td>(18)</td>
<td>6.94</td>
<td>(1.23)</td>
</tr>
</tbody>
</table>

1 y = years; mo = months; RCT = randomized clinical trial; series = case series; Retro = retrospective study; Pt = patient; Imp = implant; cu = curettes; B = buccal; Supra = supracrestal; CPS = plastic curettes+cotton pellets+sterile saline; ERL = Er:YAG laser; ADM = AlloDerm; PD = pocket depth; BOP = bleeding on probing; CAL = clinical attachment loss; REC = mucosal recession; SPT = supportive peri-implant treatment; SBCT = subepithelial connective tissue graft.

6 months, or once every 3 to 6 months based on the patient’s needs. In group 2, nonregeneration with IP, a total of eight included studies comprised four RCTs, one case series, and three retrospective cohort studies. Defect configuration was not mentioned in detail, except for in one study. According to the IP protocol, implant surfaces were treated and polished with diamond burs and a combination use with Arkansas stone was also performed in peri-implantitis cases. In addition, one study even described a modified regenerative IP technique to create a narrow

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waist in diseased implants, which was not identical to most protocols used. For adjunctive treatment to IP, antimicrobial products (metronidazole gel with a solution of tetracycline hydrochloride), chlorhexidine solution, and citric acid were also rubbed on the implant surface after IP. Other than chemical agents and mechanical treatment, Er:YAG laser was also applied in one group. Unlike group 1—nonregeneration with IP—in some studies, a resective therapy was performed to facilitate better bone contour. Supportive peri-implant treatment was mentioned in five articles: an interval of 3 to 4 months in two studies, 6 months in two studies, and more than 6 months in the majority of one retrospective study. Five articles revealed complete clinical data with at least two parameters, including survival rate, PD, BOP, MBL, CAL, and REC.

### Risk of Bias

Based on all included articles, there were nine RCTs, four retrospective cohort studies, and four case series. In nine included RCTs, the risk of bias was summarized and evaluated (Appendix Table 1; see Appendix in online version of this article at quintpub.com/journals). As for random sequence generation, two studies (22.2%) in the same group showed an unclear risk of bias, while four studies (44.4%) showed an unclear risk of bias for allocation concealment. In view of blinding of participants and personnel and outcome assessment, only one (11.1%) and two (22.2%) studies showed a low risk of bias for allocation concealment. In view of blinding of participants and personnel and outcome assessment, only one (11.1%) and two (22.2%) studies showed a low risk of bias for allocation concealment.

In four retrospective cohort studies, four case series with a prospective design, three of eight (37.5%) studies with a control group could be observed, and all included articles showed predefined indication criteria for treatment, which described the definition of peri-implantitis in detail (Appendix Table 2). In all, the summary assessment disclosed four high, one moderate, and three low risk of bias for eight articles, and the result in the present review showed the primary and secondary outcomes based on moderate risk.

### Table 2b Implantoplasty (IP)+ Nonaugmentative Treatment

<table>
<thead>
<tr>
<th>Study/year</th>
<th>Follow-up time</th>
<th>Study type</th>
<th>Pt/imp</th>
<th>Defect Type</th>
<th>Implant-plasty</th>
<th>Location</th>
<th>Other methods</th>
<th>Bone resection</th>
<th>PDO (mm)</th>
<th>BOP0 (%)</th>
<th>CAL0 (mm)</th>
<th>RECO (mm)</th>
<th>SPT</th>
<th>Failed implant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romeo et al (2005, 2007)</td>
<td>3 y</td>
<td>RCT</td>
<td>10/19</td>
<td>No data</td>
<td>Diamond + stone + polisher</td>
<td>Supra</td>
<td>Metro Gel + tetracyclin</td>
<td>Cu+ chisel (remove peaks)</td>
<td>5.79 (1.60)</td>
<td>2.83 (0.47)</td>
<td>5.5 (1.49)</td>
<td>0.5 (0.91)</td>
<td>No detail</td>
<td>0</td>
</tr>
<tr>
<td>Pommer et al (2018)</td>
<td>9 y</td>
<td>RETRO</td>
<td>47/47</td>
<td>No data</td>
<td>Diamond drills</td>
<td>No detail</td>
<td>No data</td>
<td>No data</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>No detail</td>
<td>6</td>
</tr>
<tr>
<td>Pommer et al (2016)</td>
<td>9 y</td>
<td>RETRO</td>
<td>23/23</td>
<td>No data</td>
<td>Diamond drills</td>
<td>No detail</td>
<td>ERL</td>
<td>No data</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>No detail</td>
<td>4</td>
</tr>
<tr>
<td>Englezos et al (2018)</td>
<td>2 y</td>
<td>Series</td>
<td>25/25</td>
<td>No data</td>
<td>Carbon fibered + ultrasonic scaler + diamond + stone + rubber bur</td>
<td>No detail</td>
<td>CHX</td>
<td>Osteoplasty</td>
<td>100</td>
<td>–</td>
<td>–</td>
<td>3–4 mo SPT</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Dalago et al (2019)</td>
<td>3 y</td>
<td>RCT</td>
<td>8/8</td>
<td>No data</td>
<td>Diamond bur</td>
<td>No detail</td>
<td>Citric acid</td>
<td>No resection</td>
<td>6.38 (0.53)</td>
<td>4.50 (0.57)</td>
<td>–</td>
<td>–</td>
<td>6 mo SPT</td>
<td>0</td>
</tr>
<tr>
<td>Biachini et al (2019)</td>
<td>2–6 y</td>
<td>RETRO</td>
<td>23/23</td>
<td>No data</td>
<td>Modified protocol with diamond + stone + polisher</td>
<td>Supra</td>
<td>Citric acid</td>
<td>Bone contouring</td>
<td>100</td>
<td>–</td>
<td>–</td>
<td>6 mo SPT</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Lasserre et al (2020)</td>
<td>6 mo</td>
<td>RCT</td>
<td>15/15</td>
<td>Bl &gt; 25%–50%</td>
<td>Diamond bur</td>
<td>Supra</td>
<td>Airflow + plastic nozzle</td>
<td>No resection</td>
<td>6.72 (1.78)</td>
<td>94.7 (10.7)</td>
<td>–</td>
<td>0.23 (0.48)</td>
<td>3 mo SPT</td>
<td>0</td>
</tr>
<tr>
<td>Ravida et al (2020)</td>
<td>41 mo</td>
<td>RETRO</td>
<td>19/19</td>
<td>BL &gt; 25%–50%</td>
<td>No detail</td>
<td>No detail</td>
<td>No detail</td>
<td>No detail</td>
<td>5.2 (1.6)</td>
<td>90</td>
<td>–</td>
<td>–</td>
<td>mostly &gt; 6 mo SPT</td>
<td>3</td>
</tr>
</tbody>
</table>

Y = years; mo = months; RCT = randomized clinical trial; series = case series; RETRO = retrospective study; Pt = patient; Imp = implant; cu = curettes; B = buccal; Supra = supracrestal; Metro gel = metronidazole gel; CHX = chlorhexidine; ERL = Er:YAG laser; PD: pocket depth; BOP: bleeding on Probing; CAL: clinical attachment loss; REC: mucosal recession; SPT: supportive-peri-implant treatment.
**Results for Implant Survival Rate**

Thirteen included articles reported the value of survival rate after IP, among which six\(^\text{23,25–29}\) articles had regenerative therapy and the other seven\(^\text{31,33–38}\) articles utilized a nonregenerative strategy for treating peri-implantitis cases. Results showed a 97% (95% CI: 0.95 to 1.00) implant survival rate in the regenerative group and 94% (95% CI: 0.90 to 0.98) in the nonregenerative group (Fig 2a) without any statistical difference.

**Result for Other Clinical Parameters (PD, BOP, MBL, CAL, and REC)**

For PD change, both the regenerative treatment group\(^\text{6,28–31}\) and nonregenerative group\(^\text{31,33,34,37}\) showed similar outcomes: 2.60 mm (95% CI: 2.25 to 2.95 mm) and 2.25 mm (95% CI: 1.92 to 2.57 mm), respectively, without any significant difference. However, high heterogeneity was also found (Fig 2b). As for BOP, despite high heterogeneity and limited sample size, all included...
articles showed approximately 40% to 60% improvement. The regenerative group revealed 3.08 mm (95% CI: 1.99 to 4.17 mm) bone gain, while nonregenerative treatment only had 0.5 mm (95% CI: 0.16 to 0.84 mm) bone gain (Fig 2c). For CAL, the regenerative group showed significantly higher clinical attachment gain (WMD: 1.74 mm; 95% CI: 1.23 to 2.24 mm) with low heterogeneity compared to the nonregenerative group, which included only one study (Fig 2d). In all articles mentioning REC, a limited mean value of 0.89 mm (95% CI: 0.67 to 1.11 mm) and 0.7 mm (95% CI: 0.37 to 1.03 mm) was revealed in the regenerative and nonregenerative groups, respectively; however, high heterogeneity was observed (Fig 2e).

**DISCUSSION**

Implantoplasty with Mechanical Treatment for Peri-implantitis

Among various treatment modalities for peri-implantitis, surgical treatment has been regarded as a better approach since it provides proper access for defect debridement and implant surface decontamination. Several tools have been proposed for decontaminating implant surfaces, including but not limited to air-abrasive devices, titanium curette, titanium brush, and IP. To explore the effect of these devices, a scanning electron microscope was used to assess surface topography and roughness as well as the degree of biofilm removal. Interestingly, although all these mechanical tools might cause surface alteration, IP seems to be a better choice for debris removal and surface smoothness when combined with Arkansas stone.

In the present review, different IP protocols with heterogeneity (eg, locations of implant and sequence of instrumentation) were performed in related literature. Unlike other studies aiming at only the supracrestal part of the implants, three...
studies\textsuperscript{21–23} from the same group advocated that the locations should be both supracrestal and buccal areas, while no superiority in all clinical parameters was found. As for the sequence of IP instrumentations, there had not been one gold standard to follow except for the additional use of polishing stones after diamond burs,\textsuperscript{43} which was in agreement with most included studies.\textsuperscript{21–24,26–29,31,32,35,38} When comparing the present findings to previous studies and reviews associated with the surgical approach but without the IP approach, similar study outcomes were found. The surgical approach without IP in previous studies showed an 81.7\% to 86\% long-term implant survival rate (vs the present study, which showed 94\% for nonregeneration with IP and 97\% for regeneration with IP), 2.1 to 2.7 mm PD reduction (vs 2.25 mm for nonregeneration with IP and 2.6 mm for regeneration with IP), and 2.1 to 2.7 mm radiographic bone fill (vs 0.5 mm for nonregeneration with IP and 3.1 mm for regeneration with IP).\textsuperscript{39,44–48} These intriguing observations could be basically attributed to the differences in defect types and surgical modalities. Nevertheless, the polished surface of implants after IP makes treated implants easy to maintain not only for home care but also for professional cleaning, which could permit more favorable outcomes in IP-managed peri-implantitis defects. To re-evaluate the necessity of IP, the controversial issue has been re-investigated in current studies with statistical evidence.\textsuperscript{34,37} One retrospective study claimed limited benefits could be obtained with IP; however, uneven distribution of bone loss of 25\% to 50\% at baseline in both groups and the lack of detail on treatment protocols should be mentioned, which had been regarded as potential risk indicators.\textsuperscript{37} Compared to the air-abrasive device, one RCT revealed comparable effectiveness in disease resolution within only 6 months.\textsuperscript{34} Therefore, well-designed RCTs with similar destruction at baseline, standardized treatment protocols, and long-term follow-up are required to truthfully investigate the necessity of IP during treatment.

Several current concerns associated with IP are the weakening of implant strength, heat, and the titanium particles\textsuperscript{49} that the procedure generates, which may have impacts on mechanical and biologic complications,\textsuperscript{12} including bending and fracture resistance,\textsuperscript{13,50,51} thermal change,\textsuperscript{52} and biocompatibility.\textsuperscript{10} Although the IP procedure might appear to weaken implant strength, the concerns are only applied in narrow implants with a diameter < 4 mm.\textsuperscript{12,13,50,51} Excess heat generated during the IP procedure is also not a major challenge with sufficient water sprays, which could be irrelevant to long-term implant stability.\textsuperscript{12,52} For titanium particles, a controversial report existed\textsuperscript{49} but without any clinical documented detrimental effects.\textsuperscript{12} Nonetheless, this is a gray area that requires more studies to investigate its true influence. However, based on all currently available studies, the IP could be a valuable clinical tool to remove contaminated implant surfaces\textsuperscript{7} and improve implant smoothness,\textsuperscript{43,51} which provides adequate wettability for cell adherence.\textsuperscript{10}

### Clinical Outcomes of Regenerative Treatment with IP in Peri-implantitis

Using the surgical regeneration approach to treat peri-implantitis is preferred by many clinicians; however, the outcome of the procedure remains limited.\textsuperscript{53,54} This can probably be attributed to the following reasons: First, all related studies conducted heterogeneous surgical protocols for mechanical treatment, and only a few articles performed IP for the supracrestal part of surface decontamination. Second, a lack of a comprehensive evaluation from baseline to long-term follow-up was noted in most studies, which might either under- or overestimate the impact of surgical treatment.

Results from this study demonstrated that the surgical approach (regeneration or nonregeneration) with adjunctive IP achieved a favorable treatment outcome in terms of managing peri-implantitis defects. However, regeneration with IP had better radiographic bone fill than nonregeneration with IP. In terms of disease resolution, the nonregenerative technique has been regarded as an effective method to reduce PD and eliminate inflammation in peri-implantitis cases.\textsuperscript{55,56} As stated, regenerative treatment could achieve comparable outcomes with a better radiographic bone fill, but it increases the complexity of treatment, additional expense, and patient morbidity.\textsuperscript{53} In addition, because of the difficulty in reentry after treatment in peri-implantitis, most studies advocated favorable outcomes in regeneration based on radiographic bone fill rather than histologic evidence. Hence, superior CAL gain from the present review should be interpreted with caution due to the lack of robust evidence of reosseointegration.

Despite the heterogeneity of surgical protocols and defect configurations, the present review suggested a favorable survival rate in both treatment groups under certain conditions, which might shed light on the implications of case selection. Regarding defect configurations in the regenerative group, most defects were combined types I and II,\textsuperscript{30,57} which represented the destruction with both supra- and infraosseous components. To be more specific, the description in related studies showed that a mean value of approximately 2 to 4 mm supraosseous and infraosseous destructions at baseline had a 3-mm bone level gain.\textsuperscript{77,78} As for other aspects of defect description, one study, which showed positive bone gain with defect angulation < 30 degrees, could imply its influence on treatment outcomes.\textsuperscript{78} Last but not least, plaque control could be one of the most critical factors in preventing peri-implant disease.\textsuperscript{56,59}
and maintaining favorable outcomes after surgical treatment.58 Despite the various maintenance strategies in the present review, in agreement with the previous meta-analysis, a tailored protocol with different recall intervals could be more practical for long-term stability.58

Limitations and Implications

In this review, several limitations should be mentioned as follows: (1) small sample size in related studies; (2) limited RCTs with moderate risk; (3) heterogeneity in defect configuration, treatment protocols, and follow-up time; (4) absence of description in case selection at baseline in regenerative and nonregenerative studies; (5) only publications written in English were included; and (6) absence of histologic evidence in most related studies since reentry with biopsy might cause ethical issues.

Although many included studies lack information on defect type and bone level alteration, the observations obtained from this review could suggest a favorable regeneration outcome in peri-implantitis defects, especially in intraosseous components with 4 mm in depth. On the contrary, suprastructure defects might be more suitable for a nonregenerative approach.31,32,34,38 Furthermore, MBL of defects was nearly unchanged in most included studies, even with the application of IP and additional osteoplasty.31,32,38 Therefore, more high-quality clinical trials with a complete description of defect configurations and treatment sequences are needed to elucidate these intriguing issues.

CONCLUSIONS

Data from this study suggested that regeneration and nonregeneration approaches with implantoplasty surface decontamination resulted in a high implant survival rate and peri-implantitis resolution. Although no differences were found in the majority of clinical parameters in both groups, the regenerative approach resulted in more radiographic bone fill than the nonregenerative treatment.

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REFERENCES


## APPENDICES

### Appendix Table 1  Quality Assessment and Risk of Bias of Included RCTs

<table>
<thead>
<tr>
<th>Study</th>
<th>Random sequence generation</th>
<th>Allocation concealment</th>
<th>Blinding of participants and personnel</th>
<th>Blinding of outcome assessment</th>
<th>Incomplete outcome data</th>
<th>Selective reporting</th>
<th>Other bias</th>
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### Appendix Table 2  Quality Assessment and Risk of Bias of Included Retrospective Studies and Case Series

<table>
<thead>
<tr>
<th>Study</th>
<th>Prospective (+)/retrospective (-)</th>
<th>Inclusion of control group</th>
<th>Predefined indication criteria for treatment</th>
<th>Record of peri-implant clinical parameters (SR, PD, BOP, MBL)</th>
<th>Completeness of outcome data for each main outcome</th>
<th>Summary assessment</th>
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