Implantoplasty – provoking or reducing inflammation? – a systematic review

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TITLE PAGE

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ABSTRACT

Objectives

To evaluate clinical parameters associated with inflammation after adjunctive implantoplasty in conjunction with surgical treatment of peri-implantitis.

Materials and methods

A systematic literature search was performed in 2 databases until 29. December 2020 to find publications that report on clinical parameters after surgical peri-implantitis treatment which included adjunctive implantoplasty. Clinical studies on implantoplasty reporting on BoP as outcome were included, but other clinical or radiographic outcomes were also considered.

Results

The search resulted in 14 articles that fulfilled the inclusion criteria. The results indicated improvements of BoP and clinical parameters following surgical peri-implantitis treatment with adjunctive implantoplasty.

Conclusions

Within its limits, the findings of the present review indicated that BoP is reduced following surgical peri-implantitis treatment with adjunctive implantoplasty, and that this improvement is in line with surgical peri-implantitis treatment without adjunctive implantoplasty.

Keywords: implantoplasty, peri-implantitits, surgical treatment, implant surface modification, review

MAIN TEXT

INTRODUCTION

The use of osseointegrated implants to replace missing teeth is increasing and has become a routine treatment in dentistry. Technical or biological complications may emerge following such treatment, and studies have uncovered a high prevalence of peri-implantitis [1,2]. Peri-implantitis is an inflammatory disease as a result of microbial biofilm accumulation on the implant which in turn affects the soft and hard implant-supporting tissues [3,4].

A number of approaches to treat peri-implantitis have been investigated, and the treatments proposed involve both non-surgical and surgical means. A randomized controlled study demonstrated no difference in bleeding on probing (BoP) following non-surgical mechanical debridement with titanium curets or ultrasonic devices [5]. Laser therapy may reduce BoP compared to mechanical debridement, but otherwise the treatment modes rendered similar clinical outcomes [6]. Systematic reviews by Renvert et al. and Figuero et al. concluded that nonsurgical treatment of peri-implantitis is not effective due to limited clinical improvements and a tendency of disease recurrence [7,8].
With the limited effect of non-surgical therapy, surgical means have been considered for disease resolution. Surgical management provides direct access to the implant, facilitates removal of granulation tissue and access for implant debridement. However, studies have demonstrated modest disease resolution following surgical treatment of peri-implantitis [9-11]. Figuero et al. stated that no surface decontamination is superior to date, and there is currently no consensus on the most effective treatment [8].

One suggested approach to surgical peri-implantitis treatment is by adjunctive implantoplasty. Removal of exposed implant-threads with rotary instruments effectively removes biofilm and deposits, and furthermore renders a smooth implant surface, which in turn may reduce bacterial adhesion, growth, and facilitate professional and self-performed oral hygiene. Ideally, this adjunctive treatment may result in an implant surface which impedes bacterial colonization and facilitates soft tissue adaption. Several *in vitro* studies have demonstrated that smooth implant surfaces may enhance fibroblast growth compared to rough surfaces [12-15].

Clinical studies have suggested advantageous clinical outcomes following implantoplasty [16-18]. Clinical case reports have demonstrated resolution of peri-implantitis following treatment by open flap debridement with adjunctive implantoplasty [19], lower levels of planktonic microbial growth following implantoplasty [20] and that implantoplasty also can be combined with bone regeneration [21].

On the contrary, implantoplasty is a treatment which affects the mechanical properties of implants and the procedure may lead to excess metal debris in the surgical site. A recent systematic review on complications following adjunctive implantoplasty reported only a single case of mucosal discoloration and no fractures [22], indicating that complications may be few. It has been suggested that inflammatory cytokines, inflammatory cells and osteoclast activation increase when titanium and metal debris accumulate in the soft tissue [23], which is inevitable during an implantoplasty procedure. A recent *in vitro* study demonstrated reduced viability of gingival fibroblasts cultured in the presence of implantoplasty debris [24]. It has also been proposed that fibroblasts exposed to titanium particles and debris may induce secretion of pro-inflammatory cytokines which in turn affects the chemotaxis and recruitment of monocytes [25]. This hypothesis may imply an aggravated inflammatory reaction following debris accumulation after implantoplasty.

Considering the contradictory suggestions in the pre-clinical literature that adjunctive implantoplasty may improve clinical parameters but also lead to aggravated inflammatory reactions in the peri-implant tissues, the aim of this study was to review the inflammatory-related clinical outcomes following such treatment.

MATERIALS AND METHODS

The focus question (PICO) in the present review:

"Does implantoplasty as adjunctive treatment to open flap debridement lead to a reduced BOP frequency?"

The focus question was assessed according to the PICO strategy:

- Population: Patients with peri-implantitis.

- Intervention: Effect of surgical peri-implantitis treatment with adjunctive implantoplasty
- Comparison: Surgical peri-implantitis treatment without adjunctive implantoplasty
- Outcomes: Changes of clinical peri-implant parameters; Bleeding on probing (BoP) (primary outcome); Plaque indices (PI), Pocket probing depth (PPD), Bone level (BL), Implant survival and Clinical Attachment Level (CAL) (secondary outcomes).

Search strategy

A systematic electronic search was performed on Medline (PubMed) and Scopus.
The database Medline was searched with the following keywords:
"(periimplant* OR peri-implant*) AND (implantoplasty OR implant surface decontamination OR implant surface debridement OR implant surface modification OR implant surface detoxification OR implant threads)".
An electronic search on Scopus database was performed with the following keyword: "implantoplasty".
Publications not found with the specified electronic search were found manually by seeking references from previous publications or by manual search in the mentioned databases.

The studies were included if they met the following inclusion criteria:

- English language
- Clinical studies in humans
- Subjects treated with surgical peri-implantitis treatment including adjunctive implantoplasty as at least one of the interventions
- Follow-up period of at least 6 months
- Peri-implantitis disease at baseline
- Records of BoP at baseline and at follow-up
- At least 2 subjects included in study
- Titanium dental implants

Studies that did not meet all of the criteria above were excluded.

The search was done by screening titles and abstracts. The extracted articles from abstracts were evaluated after full-text article screening. Full-text articles that met the inclusion criteria were included in the present review. When publications from the same research group described studies with the same subjects/population with follow up in multiple articles, the publications were considered the same study.

Clinical measurements

Recordings of BoP at baseline and follow-up after adjunctive implantoplasty were evaluated. As secondary outcome variables, the clinical parameters; implant survival, PDD, PI, and CAL and the radiologic parameter BL, were investigated to map the clinical outcomes of adjunctive implantoplasty treatment.

RESULTS

A total of 913 (794 from PubMed and 119 from Scopus) potentially relevant titles or abstracts were yielded in the electronic search and 5 papers in the manual search. From the electronic and manual search, 39 and 5 papers were screened full text, respectively. Based on the inclusion criteria, 11 papers were excluded after full-text screening (Table 1). The remaining 33 articles had duplicates in terms of same articles found by the different database searches. After removal of these duplicates, the number of included studies led to 18 articles. The publications from Romeo et al. [16,17] and those from Schwarz et al. comprise the same subjects [18,26-28]. The study by Ramanauskaite and co-workers [29] included some patients also participating in the studies by Schwarz et al. [18,26-28]. It was not possible to acquire clinical data for participants exclusively in this study upon contact with the authors. After restricting the same subjects in these studies (Romeo et al. [16,17], Schwarz et al. [18,26-28]) the number of included studies was 14.
The studies from Schwarz et al. [18,26-28] and Wang et al. [38] have a randomized controlled study design (RCT), but are randomized with respect to treatment with Er:YAG laser or control treatment, in the suprabony aspect of the peri-implantitis defect prior to

regenerative therapy. Implantoplasty was conducted in the infra-bony compartment in all subjects.

Finally, 14 papers were included in the review, of which 3 controlled studies randomized with respect to adjunctive implantoplasty; Romeo et al. [16,17]; Lasserre et al. [30]; Dalago et al. [31], 8 prospective studies [18,26-28,32-38], 2 retrospective studies [29,39], and 1 retrospective case-control study [40] (Figure 1)(Table 2).

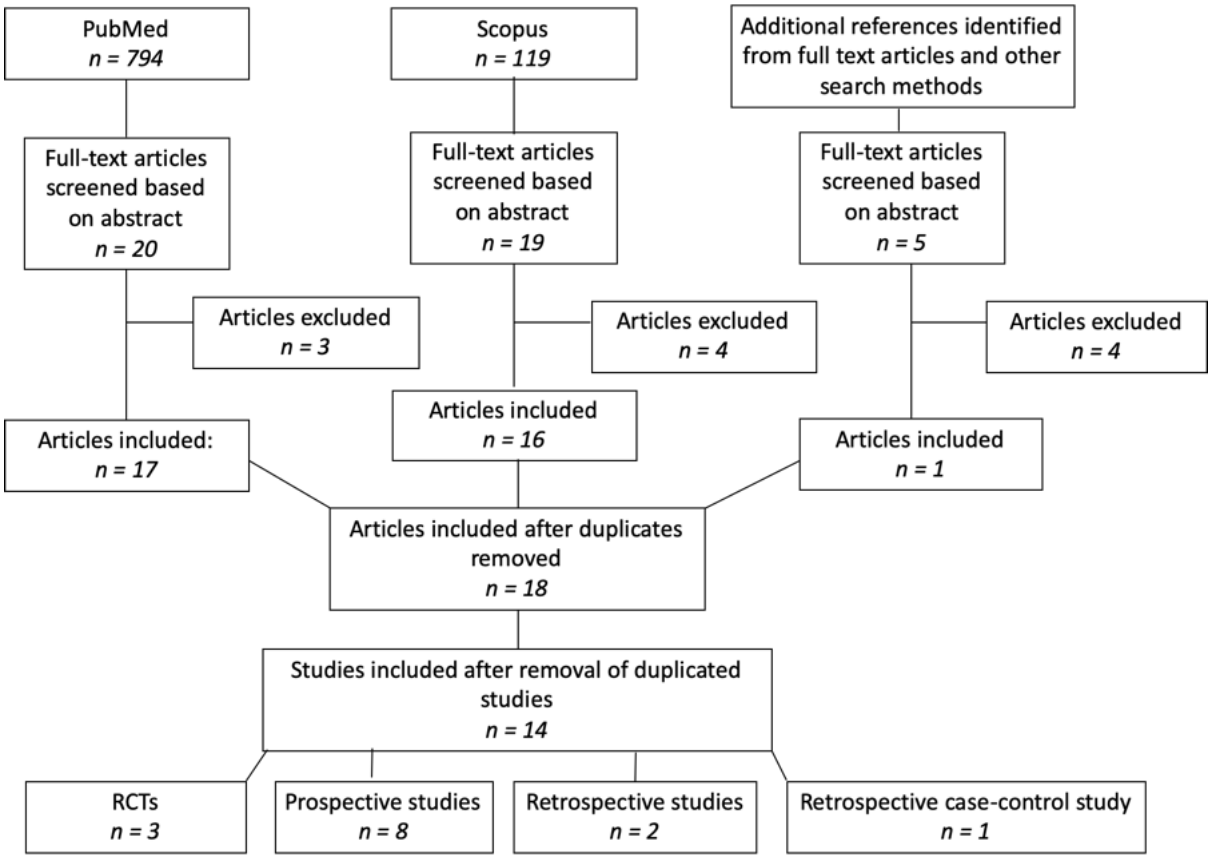

Figure 1. Flow-chart of the literature search.

INCLUDED STUDY	STUDY TYPE	PATIENTS	IMPLANTS	PERI-IMPLANTITIS DEFINITION
Romeo et al. 2005	RCT	10	19	BoP PPD>4mm BL (not specified)
Romeo et al. 2007	RCT	10	20	BoP PPD>4mm BL (not specified)
Dalago et al. 2019	RCT	8	-	BoP PPD>5mm BL>2mm
Lasserre et al. 2020	RCT	16	22	BoP/suppuration PPD $\geq$ 5mm BL $\geq$ 2 mm
Galaraga et al. 2020	PROSPECTIVE	20	28	BoP PPD$\geq$6mm BL$\geq$3mm
Ramanskauite et al. 2018	RETROSPECTIVE	39	57	BoP BL>2mm
Ravida et al. 2020	RETROSPECTIVE	19	30	Signs of inflammation BoP (suppuration) increased PPD (recession of mucosal margin) BL
Wang et al. 2020	PROSPECTIVE	24	24	BoP/suppuration PPD $\geq$ 5mm BL $\geq$ 2 mm
Schwarz et al. 2011	PROSPECTIVE	30	35	PDD>6mm BL>3mm
Schwarz et al. 2012	PROSPECTIVE	24	26	PPD>6mm BL>3mm
Schwarz et al. 2013	PROSPECTIVE	21	21	PPD>6mm BL>3mm
Schwarz et al. 2017	PROSPECTIVE	15	15	PPD>6mm BL>3mm
Schwarz et al. 2014a	PROSPECTIVE	10	13	PPD>6mm BL>3mm
Bianchini et al. 2019	RETROSPECTIVE	23	32	BoP PPD$\geq$6mm BL$\geq$3mm
Bianchini et al. 2020	PROSPECTIVE	4	4	BoP Suppuration PPD>5mm BL>3mm
Englezos et al. 2018	PROSPECTIVE	25	40	BoP PPD$\geq$6mm BL$\geq$3mm
Matarasso et al. 2014	PROSPECTIVE	11	11	BoP PPD>5mm BL>2mm
Nart et al. 2018	PROSPECTIVE	13	17	BoP/suppuration PPD>5mm BL>3mm

TABLE 2. Included studies in the present review. Data not available (-).

EXCLUDED STUDIES	REASON FOR EXCLUSION
Lozada et al. 1990	The clinical parameter BoP was not presented.
Geremias et al. 2017	The follow up period was less than 6 months.
Thierbach et al. 2013	The study did not present data for adjunctive implantoplasty separately.
Suh et al. 2003	The clinical parameter BoP was not presented.
Pommer et al. 2016	Did not present follow up measurements for BoP after implantoplasty treatment.
Schwarz et al. 2015	The clinical parameter BoP was not presented.
Schwarz et al. 2014b	Did not have more than one patient.
Sapata et al. 2016	Did not have more than one patient.

TABLE 1. Excluded studies based on inclusion criteria [19-21, 53-57].

Definition of peri-implantitis

The case definition of peri-implantitis varied among included studies, but most studies included bone loss ≥ 2 mm and BoP, and many also PPD > 5mm (Table 2).

Bleeding on Probing (BoP)

BoP was graded differently in the studies. Romeo et al. [16,17] used the mBI [41], whereas the remaining studies graded BoP dichotomously at four or six sites per implant. BoP was a requisite parameter in most peri-implantitis case definitions, but some studies included a session of non-surgical instrumentation prior to the baseline clinical assessment of BoP [18,26-30,32,33,35,36], which therefore could render a baseline BoP of less than 100%. Five studies included more than one follow-up time [16-18,26-28,30,31,38], and these demonstrated either sustained low values or further reduction of BoP over time.

Of the studies randomized with and without adjunctive implantoplasty, a significant difference between the control and test group was only observed in the study by Romeo et al. in favor of adjunctive implantoplasty [16,17] (Table 3). No differences were detected across groups in the study by Lasserre et al. [30] (2020). In the study by Dalago et al. the BoP decreased significantly from baseline to follow-up only in the group with adjunctive implantoplasty, but there was no difference between groups [31]. The retrospective case-control study by Ravida et al. did not find significant differences in BoP between the test- and

the control group, and moreover, no significant difference of BoP from baseline to follow-up was observed in the adjunctive implantoplasty group nor the control group [40].

STUDY	BASELINE BoP	3 M	Δ 3 M	6 M	Δ 6 M	12 M	Δ 12 M	24 M	Δ 24 M	36 M	Δ 36 M	48 M	Δ 48 M	5+ Y	Δ 5+ Y
Romeo et al. 2005, 2007	2.8 (2.9)			0.6 (2.2)	2.2 (0.7)	0.4 (2.7)	2.5 (0.2)	0.5 (2.3)	2.3 (0.5)	0.6 (-)	2.2				
Dalago et al. 2019	4.5 (3.6, 3)					0.5 (1.7, 1.7)	4 (1.9)	0.5 (2.1, 2.3)	4 (1.5, 1.2)	1.3 (2.7, 2.4)	3.4 (0.9, 1.2)				
Lasserre, 2020	94.7 (88) (%)	33.4 (30.8)	61.3 (49.2)	33.3 (26.3)	61.2 (61.7)										
Galaraga et al. 2020	65 (%)			16	49										
Ramanauskaite et al. 2018	100 (%)														54.9 (75)
Ravida et al. 2020	88.9 (%)					88.5	0.4								
Wang et al. 2020	0.9 (0.8)	0.6 (0.5)	0.3 (0.3)	0.5 (0.5)	0.4 (0.3)										
Schwarz et al. 2011	100 (93.3) (%)			45 (45.4)	55 (47.8)										
Schwarz et al. 2012	100 (96.6) (%)					39.9 (41.6)	60.1 (55)	45.1 (21.6)	54.9 (75)						
Schwarz et al. 2013	100 (95.2) (%)											14.8 (23.5)	85.2 (71.6)		
Schwarz et al. 2017	100 (93.3) (%)													10 (6.6)	90 (86.7)
Schwarz et al. 2014a	92.3 (%)			17.9	73.4										
Bianchini et al. 2019	100 (%)													10.7	89.3
Bianchini et al. 2020	83 (%)									12.4	70.8				
Englezos et al. 2018	100 (%)							25	75						
Matarasso et al. 2014	19.7 (%)					6.1	13.6								
Nart et al. 2018	100 (%)					29	71								

TABLE 3. BoP from baseline to post-operative measurements. Data from implants treated with adjunctive implantoplasty are presented, and data from control or parallell groups are presented in parantheses. Note that different indices were used in the studies. All numbers from the included studies are presented with 1 decimal only.

Suppuration (SoP)

Seven studies reported specifically on suppuration in addition to BoP [30,34-37,39,40]. (Table 4.). The only RCT recording SoP [30], demonstrated no difference between the groups with no significant reduction at 6 months. In Ravida et al., SoP was only significantly reduced in the adjunctive implantoplasty group from baseline to follow-up, but no significant difference was found as compared to the control group [40].

STUDY	BASELINE SoP (%)	3 M	Δ 3 M	6 M	Δ 6 M	12 M	Δ 12 M	24 M	Δ 24 M	36 M	Δ 36 M	48 M	Δ 48 M	5+ Y	Δ 5+ Y
Lasserre et al. 2020	11 (6)	4 (3)	7 (3)	4 (4)	7 (2)										
Galaraga et al. 2020	39			0	39										
Ravida et al. 2020	11					0	11								-
Bianchini et al. 2019	50													0	50
Bianchini et al. 2020	100									0	100				
Englezos et al. 2018	70							2.5	67.5						
Nart et al. 2018	88.2					0	88.2								

TABLE 4. SoP from baseline to post-operative measurements.
Implants that were treated with adjunctive implantoplasty and controls are presented. Data from implants treated with adjunctive implantoplasty are presented, and data from control or parallell groups are presented in parantheses. All numbers from the included studies are presented with 1 decimal only.

Periodontal Probing Depth (PPD)

All but one included study recorded PDD [39] (Table 5). The mean PPD at baseline in the included studies ranged from 5.2 mm to 9.5 mm.

For the studies with multiple follow-up examinations, the mean PPD either did not change considerably after the first follow-up [16,17], or increased slightly over time [18,26-28,31]. The RCT study by Romeo et al. demonstrated significant PPD reductions in both groups [16,17], but significantly more in the group that received adjunctive implantoplasty. In the RCT by Lassere et al. the PPD change was not different between groups [30]. In the study by Dalago et al. [31], there was a significant reduction in the adjunctive implantoplasty group and in one of the two control groups from baseline to follow-up, but no differences between groups. Ravida et al. reported a significant PPD reduction in both test- and control groups from baseline to follow-up, but no difference between the groups [40].

STUDY	BASELINE PPD (mm)	3 M	Δ 3 M	6 M	Δ 6 M	12 M	Δ 12 M	24 M	Δ 24 M	36 M	Δ 36 M	48 M	Δ 48 M	5+ Y	Δ 5+ Y
Romeo et al. 2005, 2007	5.8 (6.5)			3.4 (5.4)	2.4 (1.1)	3.4 (5.9)	2.4 (0.6)	3.6 (5.5)	2.2 (0.9)	3.2 (-)	2.6				
Dalago et al. 2019	6.4 (5.8, 5.7)					3.4 (4, 3.7)	3 (1.8, 2)	4 (4.4, 4.2)	2.4 (1.4, 1.3)	4.1 (4.4, 3.8)	2.3 (1.4, 1.9)				
Lasserre, 2020	6.7 (5.6)	3.4 (2.8)	3.3 (2.8)	2 .7 (2.3)	4 (3.3)										
Galaraga et al. 2020	4.6			3.4	1.3										
Ramanauskaite et al. 2018	6.8 (6.3)														2.1 (1.3)
Ravida et al. 2020	5.2					3.9	0.3								
Wang et al. 2020	6.4 (7.7)	5 (6)	1.4 (1.7)	4.6 (5.1)	1.9 (2.7)										
Schwarz et al. 2011	5.5 (5.1)			3.1 (3.4)	2.4 (1.7)										
Schwarz et al. 2012	5.2 (4.9)					3.2 (3.2)	2 (1.7)	3.7 (3.8)	1.5 (1.1)						
Schwarz et al. 2013	5.5 (5.1)											4.3 (3.8)	1.2 (1.3)		
Schwarz et al. 2017	5.8 (4.8)													3.6 (4)	2.6 (0.7)
Schwarz et al. 2014a	6.2			3.6	2.5										
Bianchini et al. 2020	5.8									1.3	4.5				
Englezos et al. 2018	8.7							3.3	5.4						
Matarasso et al. 2014	8.1					4	4.1								
Nart et al. 2018	6.5					3.5	3								

TABLE 5. PPD from baseline to post-operative measurements. Implants that were treated with adjunctive implantoplasty and controls are presented. Data from implants treated with adjunctive implantoplasty are presented, and data from control or parallell groups are

presented in parantheses. All numbers from the included studies are presented with 1 decimal only.

Plaque (PI, mPI, PI)

Plaque was recorded in all but three included studies [29,34,39]. Materasso et al. reported on full-mouth plaque scores only [33].
The studies from Schwarz et al. [18,26-28,32], Lasserre et al. [30], Gallarraga et al. [37] used PI [42]. Nart et al. [36] used the index from O´Leary et al. [43]. Romeo et al. [16,17] and Dalago et al. [31] used the modified plaque index mPI [41]. Other studies reported plaque dichotomously [35,36].
Studies with several follow-up measurements reported decreasing plaque levels throughout the observation period [16-18,26-28,32], and one study reported an initial decrease followed by a slight increase at the 3-year follow-up [31].
The RCT study by Romeo et al. [16,17] reported the same baseline values for both groups, which was reduced at all follow-ups but not significantly different between groups. In Lassere et al. [30], PI decreased significantly in both groups. In Dalago et al. [31], the mPI values decreased from baseline throughout the follow-ups in all groups, but only significantly in one of the control groups after 1 year. No significant differences were reported across groups (Table 6).

STUDY	BASELINE PI	3 M	Δ 3 M	6 M	Δ 6 M	12 M	Δ 12 M	24 M	Δ 24 M	36 M	Δ 36 M	48 M	Δ 48 M	5+ Y	Δ 5+ Y
Romeo et al. 2005, 2007	1.5 (1.5)			0.9 (1.2)	0.6 (0.3)	0.9 (1.3)	0.7 (0.2)	0.9 (1)	0.7 (0.5)	0.9 (-)	0.7				
Dalago et al. 2019	1.6 (1.3, 1.5)					1 (0.1, 0.7)	0.6 (1.2, 0.8)	0.5 (0.7, 0.3)	1.1 (0.6, 1.2)	1 (0.8, 0.4)	0.6 (0.5, 1.1)				
Lasserre et al. 2020	0.2 (0.4)	0.4 (0.4)	0.2 (0)	0.2 (0.1)	0 (0.3)										
Galaraga et al. 2020	0.5			0.45	0.05										
Wang et al. 2020	0.6 (0.2)	0.5 (0.5)	0.1 (0.3)	0.3 (0.4)	0.2 (0.2)										
Schwarz et al. 2011	0.7 (0.7)			1.2 (1.1)	0.5 (0.4)										
Schwarz et al. 2012	0.7 (0.5)					1.1 (0.7)	0.4 (0.2)	0.7 (0.3)	0.0 (0.2)						
Schwarz et al. 2013	0.8 (0.4)											0.8 (0.8)	0.0 (0.4)		
Schwarz et al. 2017	0.8 (0.2)													0.6 (0.3)	0.2 (0.1)
Schwarz et al. 2014a	0.2			0.0	0.2										
Nart et al. 2018	18 (%)					25	7								

TABLE 6. PI from baseline to post-operative measurements. Implants that were treated with adjunctive implantoplasty and controls are presented. Data from implants treated with adjunctive implantoplasty are presented, and data from control or parallell groups are presented in parantheses. Note that different indices were used in the studies. All numbers from the included studies are presented with 1 decimal only.

Clinical Attachment Level (CAL)

Four studies performed open flab debridement with adjunctive implantoplasty combined with reconstructive therapy [18,26-28,32,33,38], which in general led to substantial CAL gain. Other studies (Lassere et al. 2020; Romeo et al. 2005, 2007) did not include reconstructive treatment, which in general rendered limited CAL changes [16,17,30] (Table 7).

For studies with several follow-up measurements, Schwarz et al. demonstrated an initial CAL reduction which remained throughout the follow-up [18,26-28]. In Romeo et al. where no reconstructive treatment was performed, CAL was stable in the adjunctive implantoplasty group but increased successively in the control group [16,17]. The RCT by Lassere et al. presented significant CAL reductions in both groups [30].

STUDY	REGENERATIVE TREATMENT	BASELINE CAL (mm)	3 M	Δ 3 M	6 M	Δ 6 M	12 M	Δ 12 M	24 M	Δ 24 M	36 M	Δ 36 M	48 M	Δ 48 M	5+ Y	Δ 5+ Y
Romeo et al. 2005, 2007		5.5 (6)			5.6 (6.4)	0.1 (0.4)	5.7 (7.3)	0.2 (1.3)	5.9 (7)	0.4 (1)	5.2 (-)	0.3				
Lasserre et al. 2020		7 (6.2)	4 (3.8)	3 (2.4)	3.5 (3.4)	2.5 (2.8)										
Wang et al. 2020	+	6.9 (7.4)	6 (6)	0.9 (0.4)	5.5 (5.5)	1.5 (1.9)										
Schwarz et al. 2017	+	7.1 (6.8)													4.4 (4.7)	2.7 (2.1)
Schwarz et al. 2014a	+	6.7			4.6	2.1										
Matarasso et al. 2014	+	9.7					6.7	3								

TABLE 7. CAL clinical values from baseline to post-operative measurements. Implants that were treated with adjunctive implantoplasty and controls are presented. Data from implants treated with adjunctive implantoplasty are presented, and data from control or parallell groups are presented in parantheses. All numbers from the included studies are presented with 1 decimal only.

Bone level (BL)

Ten studies measured BL changes [16,17,30,31,33-36,38-40] (Table 8). The studies that did reconstructive treatment demonstrated mean BL gain [33,36]. Studies without reconstructive therapy presented contrasting results as either mean BL loss [31,35], slight BL gain [30,34], or sustained BL values [16,17,39] were reported.

One of the studies that reported several follow-up measurements demonstrated no change of BL during the study period in the adjunctive implantoplasty group and BL loss in the control group (significant difference) [16,17]. In Dalago et al. loss of BL was observed in both test group and control groups over follow-up [31]. There was a slight BL gain in both groups in the study by Lassere et al. [30]. The retrospective case-control study by Ravida et al. showed BL loss in both groups and no difference between the groups for annual BL [40].

STUDY	REGENERATIVE TREATMENT	BASELINE BONE LEVEL (mm)	3 M	Δ 3 M	6 M	Δ 6 M	12 M	Δ 12 M	24 M	Δ 24 M	36 M	Δ 36 M	48 M	Δ 48 M	5+ Y	Δ 5+ Y
Romeo et al. 2005, 2007		3.9 (3.5)					3.9 (4)	0 (0.5)	3.9 (4.5)	0 (1)	3.9 (5.4)	0 (2.1)				
Dalago et al. 2019		5.5 (5, 4.3)					5.9 (5.3, 4.5)	0.4 (0.3, 0.2)	6.2 (5.4, 4.5)	0.7 (0.4, 0.2)	6.4 (5.5, 4.7)	0.9 (0.5, 0.4)				
Lasserre, 2020		4.7 (5.2)	-		4.5 (4.7)	0.2 (0.5)										
Ravida et al. 2020		3.6					4.3	0.7								
Wang et al. 2020	+	-				1.1 (1.3) (bone gain)										
Bianchini et al. 2019		4.4													4.5	0.1
Bianchini et al. 2020		5									4.3	0.7				
Englezos et al. 2018		5.4							5.6	0.2						
Matarasso et al. 2014	+	8					5.2	2.8								
Nart et al. 2018	+	4.3					1.2	3.1								

TABLE 8. BL (bone level) from baseline to post-operative measurements. Implants that were treated with adjunctive implantoplasty and controls are presented. Data from implants treated with adjunctive implantoplasty are presented, and data from control or parallell groups are presented in parantheses. All numbers from the included studies are presented with 1 decimal only.

Implant Survival

Implant survival strongly reflected the years of follow-up in the various included studies (Table 9), and the implant survival ranged from 81% to 100%.
In the RCT studies a higher implant survival in the group treated with adjunctive implantoplasty compared to the control groups was found in Romeo et al. and Dalago et al. [16,17,31], but in the study by Lassere et al. a lower implant survival was reported in the adjunctive implantoplasty group compared to the control group [30]. The retrospective case-control study by Ravida et al. reported higher implant survival in the adjunctive implantoplasty group compared to the control group after a minimum of 1-year follow-up [40]. Importantly, no significant differences were reported between groups in any of the studies for this outcome.

Post-operative peri-implant maintenance program

The frequencies and means of post-operative supportive maintenance following surgical treatment of peri-implantitis with adjunctive implantoplasty varied considerable among studies. A detailed description of the supportive maintenance administered can be found in Table 9, but not all studies disclosed this.

STUDY	IMPLANT SURVIVAL (%)	FOLLOW-UP PERIOD	MAINTAINCE PROGRAM
Romeo et al. 2005; 2007	100	36 M	-
Dalago et al. 2019	100	36 M	Weekly plaque control in the first month and reinforcement of oral hygiene and prophylaxis every 6 months (not specified).
Lasserre et al. 2020	91	6 M	Post-operative care was provided at 1 week and 3 months prior to the final 6 months evaluation. Oral hygiene instructions and supragingival cleaning were given at 3 and 6- month evaluation.
Galaraga et al. 2020	100	6 M	-
Ramanskauite et al. 2018	100	6 M -10.5 Y	-
Ravida et al. 2020	90	>12 M	-
Wang et al. 2020	100	6 M	Post-operative supragingival debridement around implants at 3 and 6 months after baseline.
Schwarz et al. 2011-2017	81	6 Y	Every second week during the first 2 months after surgery, then monthly during the first 6 months to control oral hygiene and wound healing. Thereafter every six months after the first year. After the 2nd year annual professional cleaning and hygiene reinforcement.
Schwarz et al. 2014a	100	6 M	Controls every second week during the first 2 months, and thereafter maintenance every third month.
Bianchini et al. 2019	87	24 M	-
Bianchini et al. 2020	100	36 M	-
Englezos et al. 2018	100	24 M	Recall between 1 to 3 months after therapy, and the frequency decreased from 2-4 times a year based on individual needs.
Matarasso et al. 2014	100	12 M	Controls were performed weekly during the first six weeks of healing, and at a 3-6 months interval in the following time based on individual risk assessment.
Nart et al. 2018	100	12 M	Post-operative care was provided every second week in the first month, and then scheduled every 2 months.

TABLE 9. Overview of maintenance following adjunctive implantoplasty. Only data for implants that received adjunctive implantoplasty treatment are presented. Data not available (-).

Implantoplasty protocols

The protocols for adjunctive implantoplasty can be found in Table 10. Diamond burs was the most frequently employed bur.

PROTOCOL TYPE	**STUDY**
A	Englezos et al. 2018 Matarasso et al. 2014 Romeo et al. 2005;2007 Bianchini et al. 2019;2020
B	Schwarz et al. 2014a Ramanskuaite et al. 2018 Schwarz et al. 2011-2017 Nart et al. 2018 Gallarraga et al. 2020
C	Dalago et al. 2019 Lassere et al. 2020
D*	Ravida et al. 2020
Not specified	Wang et al. 2020

TABLE 10. Protocol used for adjunctive implantoplasty

A: Diamond bur(s) + Arkansas stone + Silicone bur(s).

B: Diamond bur(s) + Arkansas stone.

C: Diamond bur(s).

D: Carbide bur(s) + Silicone bur(s).

* Not all implants were treated with silicone burs.

DISCUSSION

The results from the present review indicated improvements of clinical parameters following surgical peri-implantitis therapy with adjunctive implantoplasty compared to baseline. In studies which included a control group of surgical peri-implantitis treatment without adjunctive implantoplasty, similar outcomes were for the most part observed.
It is not the objective of this scoping review to compare clinical outcomes following surgical peri-implantitis treatment with or without adjunctive implantoplasty, but to review the inflammatory-related clinical outcomes after adjunctive implantoplasty. Collectively, this data indicates that an aggravated inflammatory reaction as a result of titanium and metal debris was not reflected in the clinical data that has been published to date. The literature seems to suggest clinical improvements of the clinical parameters assessed, and with no pronounced difference whether adjunctive implantoplasty was performed or not. Follow-up studies for several years exist, and the findings indicate a lasting outcome. This suggests that a potential clinical effect of the suggested "inflammatory-aggravated" situation may not be detected for the first few years after treatment. There are however few long-term studies, and the included studies vary considerably in design.

As BoP was a prerequisite for inclusion in the studies it is not surprising that BoP decreased from baseline to the first follow-up appointment. Only one study reported similar BoP at follow-up and baseline, and this was found in both test and control groups [40]. The reason for this may be related to the retrospective case-control design which included subjects with different history of peri-implant maintenance attendance following surgical treatment with or without adjunctive implantoplasty. They reported that clinical outcomes were influenced by the frequency of peri-implant maintenance attendance and not by adjunctive implantoplasty [40]. Five studies included more than one follow-up, and the improvements in BoP was without exception maintained beyond the first follow-up. Thus, clinical signs of inflammation in peri-implant tissues did not seem to increase with time after surgical peri-implantitis treatment with adjunctive implantoplasty. Romeo et al. was the only study to find a statistically significant difference in BoP in favor of adjunctive implantoplasty over the control group [16,17].

Importantly, studies on surgical peri-implantitis treatment performed without adjunctive implantoplasty are in line with the results presented here. Sustained improved BoP values

have been demonstrated over multiple follow-up appointments [44-47], but studies have also reported an increase of BoP over follow-up after the initial drop from baseline to the first follow-up [10,11,48-51].

The outcome PPD was in line with BoP. With the exception of Romeo et al. [16,17], no differences were observed between groups in studies with control groups. Mean PPD values remained low in studies with multiple follow-ups [16-18,26-28,30-32,38].
The same findings have been reported in studies addressing peri-implantitis surgery without adjunctive implantoplasty. Mercado et al. demonstrated stable PPD over a three-year follow-up after peri-implantitis surgery in combination with reconstructive treatment [45]. Stable PPD has also been reported over a 12-month follow-up in studies without the use of regenerative treatment [50,51]. However, studies have also reported increased mean PPD over follow-up time both with and without reconstructive treatment in conjunction with surgical peri-implantitis treatment [10,49].

Facilitated plaque removal and impeded microbial adhesion are often advocated as rationales for adjunctive implantoplasty. The mean mPI was consecutively lower in the adjunctive implantoplasty group but not significantly in Romeo et al. [16,17]. In all the other studies with control groups, no effect of adjunctive implantoplasty on plaque indices were reported [30,31,40]. In general, mean PI values decreased from baseline which is to be expected after treatment and inclusion in a study.

In studies with control groups no mean BL changes were reported according to adjunctive implantoplasty [30,31,40], with the exception of the study by Romeo et al. [16,17], where successive loss of bone in the control group was demonstrated compared to stability in the test group. The studies that assessed BL following peri-implantitis surgery with adjunctive implantoplasty in combination with reconstructive therapy naturally demonstrated BL gain [33,36], indicating that this treatment modality also can be combined with reconstructive therapy. This has also been demonstrated in reconstructive treatment without adjunctive implantoplasty [52]. Importantly, none of the included studies assessed BL changes over more than one time point, which points to the lack of evidence over time of outcomes after reconstructive treatment combined with adjunctive implantoplasty.

In studies that employed reconstructive treatment in conjunction with peri-implantitis surgery, but without adjunctive implantoplasty, some evidence exists. La Monaca and co-workers [49], demonstrated an increase of bone level by approximately 1.5 mm from baseline to 1-year follow-up after reconstructive peri-implantitis treatment, followed by a successive loss of BL until the 5-year follow-up with BL returning to baseline levels. However, studies have also showed BL stability over follow-up time both with and without reconstructive treatment in conjunction with peri-implantitis surgery [10,45].

None of the included case-control or RCT-studies reported a significant difference of implant survival, which may not be surprising considering the limited follow-up. The reported survival rates in the included studies between 81% and 100% corroborates studies on surgical peri-implantitis treatment without adjunctive implantoplasty [10,44,47-51].

Several different implantoplasty protocols were used in the included studies. The choice of protocol may be of clinical relevance as it may influence both surface roughness parameters but also the debris composition. It is therefore possible that the choice of burs for implantoplasty may be related to a potential inflammatory-aggravating effect. No study was identified that included more than one protocol, and hence, the clinical impact of different burs used for implantoplasty is not known.
The impact of peri-implant maintenance therapy frequency following surgical treatment is well documented [45]. In the studies included, the maintenance frequency interval for most studies ranged between 3-6 months, but also yearly after the first year. The frequency interval and quality of maintenance therapy may be more related to clinical outcomes related to inflammation (e.g. BoP, PPD) over time than the effect of the adjunctive implantoplasty per se, which was demonstrated in the study by Ravida et al. [40].

In the present review, parameters from clinical studies on adjunctive implantoplasty has been discussed in light of a potential inflammatory-aggravated effect on peri-implant tissues. A meta-analysis was not performed due to the very different methodology in the included studies. Inclusion criteria, preoperative non-surgical debridement, implantoplasty protocol, resective or reconstructive treatment approach and post-surgical maintenance frequency were all factors that differed substantially between studies. There is also high risk of bias in many

of the studies included. Not all studies provided information about every parameter except for BOP, which was an inclusion-criteria in this review.
In this review only mean values have been discussed. It is well known that any increase or decrease of a clinical parameter very often represents deterioration or healing in few or single patients. Nevertheless, mean numbers are useful to address the aim of the study, and considering a potential inflammatory-aggravating effect of implantoplasty.
Implant surface characteristics was not included in all studies and was not considered in this review. This factor further adds to the heterogeneity among the studies and points to the complexity of comparing outcomes of treatment. Although implantoplasty effectively may remove biofilm and hard deposits on implants, it is presumably hardly performed on machined implant surfaces because it would result in a rougher surface. The study by Romeo et al. [16,17] was the only study presenting a clear advantage of adjunctive implantoplasty (significant reductions in PPD, CAL, mBI and BL) of the studies that had a control group. This may be related to the fact that all implant surfaces in the study were titanium-plasma sprayed, which may suggest that adjunctive implantoplasty may be efficacious for some implant surfaces, but not for others.

CONCLUSIONS

The data from the included studies indicate that surgical peri-implantitis treatment with adjunctive implantoplasty leads to a reduction in BoP, and that this is in line with data presented in studies on peri-implantitis surgery without adjunctive implantoplasty. In general, this was also the case for the secondary outcomes PDD, BL, CAL and plaque indices.
With the exception of one randomized clinical study, there is no evidence that adjunctive implantoplasty is superior or inferior in reducing clinical parameters associated with inflammation. A potential clinical effect of a suggested “inflammatory-aggravated” impact following adjunctive implantoplasty is not evident considering the existing literature, at least not for the first years after treatment.

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