Resective surgical treatment of peri-implantitis: an integrative review

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Abstract

***Objectives*: This review aimed to analyze the resective surgical treatment of peri-implantitis (PI), evaluating whether it is an effective approach.**
Methods: An electronic search was done through the PubMed/MedLine and Online Knowledge Library (B-On) databases from 2011 to 2022. The section of studies was guided by reading the title, the abstract, and the full-text reading of the article. It included randomized controlled trials (RCTs), only clinical studies, and articles in the English language addressing the resective surgical treatment of PI, taking into account the respective parameters: probing depth (PD), bleeding on probing (BoP), marginal bone loss (MBL), and microbiological data.
***Results*: According to the bibliographic research, we found 325 articles; therefore, only seven were included for full-text reading and integrated into this review. Over 401 implants were studied in 221 patients diagnosed with PI and treated with different resective surgical approaches. Two of the studies included had a 24-month follow-up; one had 12 months; two had a duration of 36 months; one of 3 months; and one study had 6-month follow-up. Regarding the mean age of the patients, an average of 59.3 years was found. All studies included both smoking and non-smoking patients, but these did not show any negative effects on surgical resective treatments for PI. There was a large heterogeneity of methods for treating PI: (1) resective surgery with osteoplasty and surface debridement (implantoplasty, IP); (2) the use of medications/antiseptic (0.12% chlorhexidine + 0.05% cetylpyridinium chlorine) or acids (phosphoric acid 35%); and (3) adjunctive use of laser. The best PD reduction result obtained was found in Bianchini et al.'s study, with a 75% PD decrease. The best result for %BoP reduction was present by Papadopoulos et al., with an average reduction of 73% and 67%, respectively, approaching PI with an isolated "open flap" debridement and adding laser. The best result for MBL was obtained by Englezos et al., with a difference of 4.9 mm.**
***Conclusion*: The resective surgical treatment of PI effectively reduced clinical parameters (PD, BoP, MBI, and inflammation) in the tissues affected by PI. More scientific evidence is limited regarding the success of this treatment of PI; however, additional scientific studies with a more significant number of patients and longer follow-ups are necessary.**

Keywords: Resective surgery, Periodontics, Dental implants, Peri-implantitis, Surgical treatment.

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Introduction

The placement of dental implants worldwide has increased exponentially in recent years. This growth, as well as the multiple complications associated with its practice, highlights the need for clinical studies that relate these factors to the appearance of peri-implant pathologies [1,2]. Peri-implant mucositis (PIM) is defined as a transient inflammatory lesion in the soft tissues surrounding the implant, whereas peri-implantitis (PI) is a pathological state associated with bacterial plaque [3] that adheres to the tissues around the implant and is characterized by loss of supporting tissue and inflammation of the soft tissues [4]. The prevalence of mucositis can be achieved in 50% of the implants installed, while in PI, it was between 12% and 43% of the implants [5,6]. The etiology of these conditions originates in the formation of plaque resulting from an accumulation of bacteria [3] that is deposited and aggregated on the implant's surface [8]. PI is a condition that has a more established and chronic duration over time. The lesions present clinical signs such as inflammation, increased probing depth and/or suppuration, and radiographically presenting bone loss [7].

Dental implants can have bacterial adhesion on their surface, which has a certain roughness; this characteristic has an exponential effect on promoting oral biofilm adhesion, increasing inflammation, and, consequently, loss of supporting bone [9,10]. The macro [11,12] and microstructure of the implant surface [13,14], its prosthetic connection, and the constituents and design of the prosthetic component [15-17] associated with the patient's oral hygiene are fundamental points for controlling bacterial adhesion [8]. Then, the main goal of treating PI [1,18] is to resolve the existing inflammation, preserve or recover bone using bone grafts [19], and maintain a healthy state of the present soft tissues [20].

The surgical approach eliminates granulation tissue and decontaminates the implant surface [1]. Surgical treatment of PI depends on the severity of the disease. This may present a resective therapeutic approach promoting the elimination of the bone defect (osteotomy and osteoplasty), bacterial decontamination, as well as regularization and smoothing of the implant surface (implantoplasty [IP]) in the supracrestal region [21]. Flap debridement can encompass multiple therapeutic options, such as the addition of antiseptics, antimicrobials and/or bactericides, such as chlorhexidine (CHX), cetylpyridinium chlorine (CPC), laser application, use of carbon and titanium curettes, as well as specific ultrasonic instruments, contributing to the elimination of microorganisms present on the implant's surface and in the peri-implant pockets [1].

Within this context, the main objective of this review was to verify the literature that reported on resective treatment on implants affected by PI. Understanding better the result can contribute to an increased implant survival rate when affected by PI in the medium-long term.

Materials and methods

This integrative review followed the PRISMA guidelines and intended to answer two research questions: (1) "Is the resective surgical approach a predictable and effective technique to approach implants affected by peri-implant pathology?"; (2) "what is the possible prognosis for a resective surgical treatment in implants affected by PI in the medium to long term?". In methodological terms and based on the outlined objective, a search was carried out through the literature present in the online databases PubMed/MedLine and the Online Knowledge Library (B-On) over the last 11 years (2011-2022) using the following search terms: "resective" OR "osteotomy" OR "osteoplasty" OR "implantoplasty" AND "surgical treatment" AND "peri-implantitis".

Based on the aforementioned key terms, this study was developed based on the PICO strategy: Patients (P): who underwent resective surgical treatment for peri-implant lesions; Intervention (I): peri-implant health status at the beginning of treatment and after resective surgical treatment; Comparison (C): comparison between initial and final peri-implant status after resective surgical treatment; and Outcome (O): increased survival rate for the implants that underwent resective surgical therapy.

Inclusion and exclusion criteria

The inclusion and exclusion criteria for the selection of articles constituted the results of this study were: *Inclusion criteria*: (1) time frame: 11 years; (2) clinical studies; (3) language: English; (4) human studies; and (5) studies related to surgical resective therapy. The exclusion criteria were: (1) peri-implant regenerative therapy; (2) non-surgical peri-implant treatment; (3) non-clinical studies; and (4) publications in other languages.

Data evaluation

This analysis was carried out independently by two reviewers (FC and SB), and the results obtained were discussed by integrating the inclusion/exclusion criteria, title, abstract, and full-text reading.

Results

After completing the literary search on the resective surgical treatment of PI (Figure 1), seven articles [20,22-27] resulted, considering current scientific evidence. Thus, for a better understanding of the selected literature strictly related to the topic, the various objectives of each study are described below, as well as materials and methods, results, and conclusions, which are subsequently analyzed and discussed. Table 1 presents details of the studies included.

In this review, over 401 implants were studied in 221 patients diagnosed with PI; they were treated with different resective surgical approaches. Two of the studies included had a 24-month follow-up; one had 12 months; two had a duration of 36 months; one of 3 months; and one study had 6-month follow-up. Regarding the mean age of the patients, an average of 59.3 years was found. All studies included both smoking

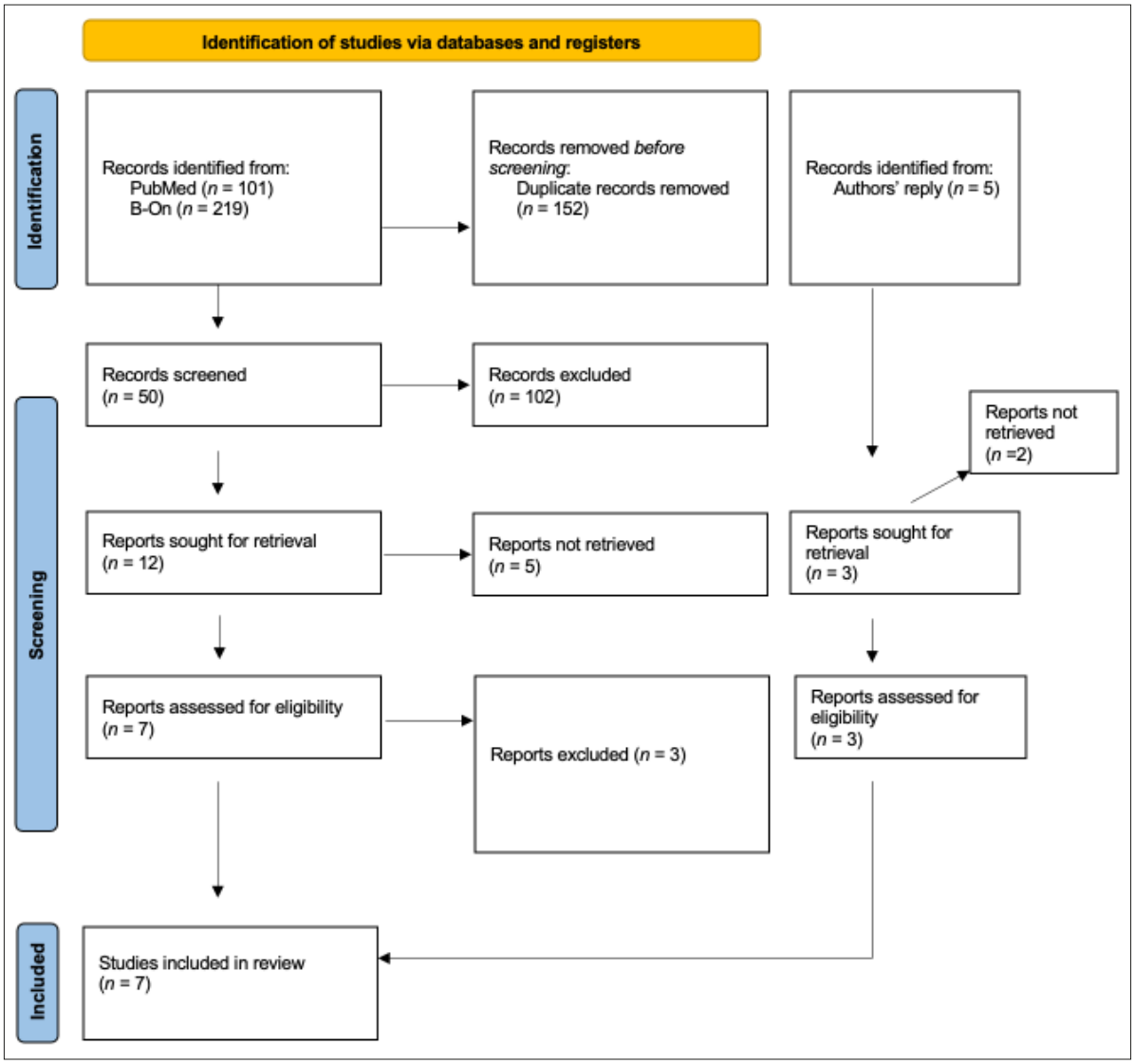

Figure 1. Prisma flowchart for selection of the studies.

and non-smoking patients, but these did not show any negative effects on surgical resective treatments for PI.

de Waal et al. (2013)[20]

This randomized, double-blind clinical study evaluated 30 patients with an average age of 60 years; 79 implants were diagnosed with peri-implantitis. The objective was to compare the effect of two therapeutic approaches after implant debridement: the first: 0.12% CHX + 0.05% CPC (test group) and the second: placebo solution (same as the first without CHX and CPC (placebo group). The load of periodontal pathogenic bacteria present, the presence of plaque, suppuration on probing (SoP), bleeding on probing (BoP), probing depth (PD), and marginal bone loss (MBL) were the criteria evaluated in this study.

Each patient was approached with the same therapy, with the same surgeon, through an apical repositioning flap associated with osteotomy/bone osteoplasty, aiming to eliminate the angular defects with a spherical drill and irrigation with saline solution. The implant was mechanically decontaminated with saline-soaked compresses. Patients were randomly assigned to the test or placebo group to undergo implant debridement with a 0.12% CHX + 0.05% CPC solution (described as the test group) or a placebo solution (described as the placebo group) for 1 minute. Finally, each implant was cleaned with saline water solution for 1 minute; the structures were repositioned apically and sutured. All patients were recommended to undergo cleaning with a 0.12% CHX + 0.05% CPC solution for 30 seconds twice a day for 2 weeks.

Of the 79 implants, 9 were lost due to persistent severe peri-implant pathology and 1 due to implant fracture after the surgical procedure. In both cases, after debridement, a significant decrease in bacterial load was observed, with a better result (R) in the test group: $R_{initial}$ (placebo) = 5.54 ± 1.23 against $R_{initial}$ (test) = 5.46 ± 1.13 and R_{final} (placebo) = 2.77 ± 2.37 against R_{final} (test) = 1.25 ± 2.11. There was a difference of 2.77 in the placebo group and 4.21 in the test group.

In the placebo group, plaque percentage was 41.7%,

BoP 95.8%, SoP 31.3%, mean PD was 5.5 mm (100% had a PD > 5 mm; 81.3% > 6mm; 95.8% had PD > 5 mm + BoP/SoP) and MBL was on average 3.6 mm. After 3 years, the results were: 50% implant with bacterial plaque, 94.7% with BoP, 15.8% with SoP, the mean PD passes through 3.7 mm (47.4% PD > 5 mm; 15.8% with PPD > 6 mm; 42.1% with PD > 5 mm + BoP/SoP and 15.8% with PD > 6 mm + BoP/SoP) and the mean MBL passed through 3.9 mm.

In the test group, the implant percentage showed a plaque index of 38.7%, BoP of 96.8%, SoP of 29.0%. The mean PD was 4.3 mm (54.8% with PD > 5 mm; 32.3 % PD > 6 mm; 48.4% PD > 5 mm + BoP/SoP and 25.8% PD > 6 mm + BoP/SoP), and the mean MBL was 5 mm. After 3 years, the results were: 50% implant with bacterial plaque, 94.7% with BoP, 15.8% with SoP, the mean PD passes through 3.7 mm (47.4% PD > 5 mm; 15.8% with PD > 6 mm; 42.1% with PPD > 5 mm + BoP/SoP and 15.8% with PD > 6 mm + BoP/SoP) and the mean MBL passed through 3.9 mm.

de Waal (2015)[22]

This study aimed to observe and compare the effect of a 2% CHX solution versus a 0.12% CHX + 0.05% CPC solution on implant debridement over a 12-month period. For this purpose, 44 patients with 108 implants were evaluated. In this randomized controlled study, patients were randomly assigned to the test group (CHX 2%) or the control group (CHX 0.12% + CPC 0.05%). Twenty-two patients were in each group: 8 men and 14 women in the control group and 5 men and 17 women in the test group.

The principle of resective surgical treatment was an apical repositioning surgery for better access to the granulation tissue and the implant. Bone remodeling, i.e., osteoplasty, with a spherical drill and abundant irrigation to eliminate bone defects. Mechanical cleaning of the implant with curettes and saline water compresses for 1 minute. Random distribution of patients (test or control groups) and implant disinfection with CHX 2% or CHX 0.12 + CPC 0.05%. Cleaning the implant with saline water for 1 minute. Finally, explanations and instructions on oral hygiene were given, and mouthwash was recommended twice a day, 30 seconds, for 2 weeks with a CHX 0.12% + CPC 0.05% solution.

In the control group, the plaque percentage was 47.5%, BoP 94.9%, SoP 49.2%, and the mean PD was 5.0 mm (100% had a PD > 5 mm; 69.5% > 6 mm; 91.5% had PD > 5 mm + BoP/SoP and 66.1 with PD > 6 mm + BoP/SoP) and the MBL was on average 4.1 mm. After 12 months, the results were 37.0% of implants with plate, 68.5% with BoP, 1.9% with SoP, the mean PD passed through 2.9 mm (18.5% PD > 5 mm; 5.6% with PD > 6 mm; 16.7% with PPD > 5 mm + BoP/SoP and 5.6% with PD > 6 mm + BoP/SoP) and the mean MBL passed through 4.1 mm.

In the test group, the percentage of implants showed a plaque index of 36.7%, BoP of 98.0%, SoP of 57.1%. The mean PD was 4.7 mm (100% with PD > 5 mm; 57.1 % PD > 6 mm; 100% PD > 5 mm + BoP/ SoP and 57.1% PD > 6 mm + BoP/SoP), and the mean MBL was 4.0 mm. After 12 months, the results were: 31.2% implant with plaque, 77.1% with BoP, 10.4% with SoP, the mean PD passes through 3.0 mm (27.3% PD > 5 mm; 8.3% with PD > 6 mm; 25% with PPD > 5 mm + BoP/SoP and 6.3% with PD > 6 mm + BoP/SoP) and the mean MBL passes through 4.3 mm.

The result (R) on the bacterial load was observed: $R_{initial}$ (control) = 5.25 ± 0.88 $R_{initial}$ (test) = 5.63 ± 0.98; and R_{final} (control) = 1.88 ± 2.2 against R_{final} (test) = 1.98 ± 2.98. A difference of 3.37 in the control group and 3.65 in the test group.

Hentenaar et al. (2018)[23]

The objective of this article was to observe and compare the effect of 35% phosphoric acid solution during surgical treatment versus saline solution over 3 months. This study comprised 28 patients with a total of 53 implants, 14 patients in each group, 22 implants in the control group (5 men and 9 women), and 31 in the test group (7 men and 7 women).

Apical repositioning resective surgery was performed for better access. Osteoplasty with a spherical drill to reduce existing bone defects. Cleaning the implant manually with curettes and saline solution compresses for 1 minute. Patients were randomly divided (test or control group), and the implant was disinfected with 35% phosphoric acid gel (pH=1) for 1 minute or sterile saline solution for 1 minute (the control solution was prepared so that no distinction could be made between the two solutions). The implant was cleaned with plenty of saline solution for 1 minute. Apical repositioning and suturing were performed. Patients were advised to rinse their mouths for 30 seconds 2x/day for 2 weeks with a 0.12% CHX + 0.05% CPC solution.

The bacterial load results were: $R_{initial}$ (control) = 5.57 ± 0.93 and $R_{initial}$ (test) = 5.35 ± 0.98; and R_{final} (control) = 2.25 ± 2.98 and R_{final} (test) = 0.81 ± 2.25. A difference of 3.32 in the control group and 4.54 in the test group was reported. At the level of clinical outcomes, in the control group, the plaque percentage was 13.6%, BoP 100%, SoP 54.5%, the mean PD was 5.3mm (100% have a PD > 5 mm; 100% > 6 mm; 100% have PD > 5 mm + BoP/SoP, 100 with PD > 6 mm + BoP/SoP). After 3 months, the results were 25% of implants with plate, 50% with BoP, 10% with SoP, the average PD passes through 3.5 mm (35% PD > 5 mm; 25.0% with PD > 6 mm; 25% with PD > 5 + BoP/SoP and 20% with PD > 6 mm + BoP/SoP).

In the test group, the percentage of implants showed a plaque index of 16.1%, BoP of 96.8%, and SoP of 80.6%. The mean PD was 5.2 mm (100% with PPD > 5 mm; 90.3 % PD > 6 mm; 100% PD > 5 mm + BoP/ SoP and 90.3% PD > 6 mm + BoP/SoP). After 3 months, the results were 9.7% implant with plate, 76.7% with BoP, 20% with SoP; the average PD passed through 4.1 mm (46.7% PD > 5 mm; 40.0% with PD > 6 mm; 36.7% with PPD > 5 mm + BoP/SoP and 33.3% with PD > 6 mm + BoP/SoP.

Bianchini et al. (2020)[24]

The results of clinical cases treated with resective surgery and implantoplasty over a 3-year period with a platform-switching concept to preserve the integrity of peri-implant tissues were presented. For this purpose,

four patients (2 women and 2 men) with an average age of 53 years were selected, and the treatment procedure was a prescription of Amoxicillin 500 mg orally 1 day before the procedure and for 7 days, and total decontamination of the oral cavity.

Intrasulcular incision around the implant and adjacent teeth of full thickness; removal of granulation tissue and biofilm present on the implant mechanically with curettes; osteoplasty with a contra-angle diamond bur, and debridement of the implant, smoothing of the implant (implantoplasty) with a fine diamond spherical bur apical to the "platform-switch", and Arkansas stone, polishing with abrasive silicone until the implant surface was completely smooth and polished. Citric acid was applied to the implant for 3 minutes, followed by saline solution and cleaning of the surgical area; the flaps were repositioned and sutured. At the end, patients were asked to rinse their mouths with CHX for 1 week.

In this study, the clinical outcomes studied were MBL, BoP, PD, SoP, and the presence of pain. At baseline, patients had a mean MBL of 4.8 mm in the mesial region and 5.1 mm in the distal region (Patient 1: M=4.1 mm/D=4.0 mm; Patient 2: M=6.0 mm/D=7.0 mm; Patient 3: M=4.5 mm/D=4.7 mm; Patient 4: M=4.7 mm/D=4.6 mm). The BoP was, on average, 83.15% (Patient 1: 83%; Patient 2: 100%; Patient 3: 83%; and Patient 4: 66.6%). The mean PD was 5.75 mm (5±0.2 mm in Patient 1; 7±0.5 mm in Patient 2; 6±0.2 mm in Patient 3; 5±0.4 mm in Patient 4). Suppuration was present in all patients, and pain was present only in patient 2.

After 3 years, the mean MBL changed to 4 mm in the mesial and 4.5 mm in the distal (Patient 1: M=4.0 mm; D=3.9 mm; Patient 2: M=3.0 mm/D=5.0 mm; Patient 3: M=4.5 mm/D=4.5 mm; Patient 4: M=4.5 mm; D=4.6 mm), with a difference of 0.3 mm. The mean BoP was 12.4% (Patient 1: 0%; Patient 2: 33%; Patient 3: 0%; and Patient 4: 16.6%), i.e., a difference of 70.75%. The mean PD was 1.25 mm (1±0.5 mm in Patient 1; 1±0.5 mm in Patient 2; 1±0.5 mm in Patient 3; 2±0.1 mm in Patient 4), with a difference of 4.5 mm. None of the patients presented pain or suppuration.

Then, the authors concluded that the platform-switch concept applied to implantoplasty is promising regarding peri-implant bone and mucosa stability over a 3-year observational period.

Englezos et al. (2018)[25]

This study aimed to evaluate the clinical and radiographic changes (mainly PD and MBL) of the peri-implant tissues with the resective treatment of PI, using implantoplasty and osteoplasty over 2 years. In this study, 25 patients with a mean age of 66.2 years (8 men [9 implants] and 17 women [31 implants] with a total of 40 implants were treated (17 Nobel®; 8 Straumann®; 8 Ankylos®; 1 Biomet3®; 2 Astra®; 2 Zimmer® and 2 IMZ®).

A defined protocol was performed, starting with a total oral disinfection. Full-thickness flaps were made for better access to the implant and the bone (with preservation of the keratinized portion of the gingival gingiva as much as possible). Granulation tissue was eliminated, osteoplasty was performed for angular remodeling of the bone with a round bur, debridement of the implant with hand curettes, and ultrasound was used. Implantoplasty with a diamond bur and Arkansas stone, polishing with abrasive rubber, and abundant irrigation. The implant was cleaned, and the site was irrigated with CHX and saline solution to remove the implant particles. The flaps were repositioned apically and sutured. Patients were asked to rinse their mouths twice daily for one week postoperatively with 0.12% CHX solution. The results of this study focus on PD and MBL. At baseline, the mean PD was 8.7 mm, and the mean MBL was 5.1 mm; after two years, the results were 3.3 mm and 5.3 mm, respectively, presenting statistically significant results ($p<0.001$) achieved for PD.

The authors concluded that the results of the study suggested that applying surgical therapy for pocket elimination associated with apically positioned flap, osteoplasty, and implant surface smoothing was effective and predictable in arresting peri-implantitis progression for 2 years. The authors also stated that compliance with meticulous daily plaque control is paramount.

Carcuac et al. (2017)[26]

This study aimed to evaluate the results of PI treatment using four techniques with bone resection (osteoplasty was used to eliminate pockets): (1) osteoplasty alone, (2) osteoplasty + systemic antibiotic (AB) (Amoxicillin 2x750 mg/day), (3) osteoplasty + antiseptic solution, and (4) osteoplasty + antiseptic solution (0.2% CHX digluconate) + systemic AB.

To this end, 67 patients with a mean age of 66.3 years (21 men and 46 women) with 121 implants were treated. The patients were randomly assigned to the following test groups: Group 1 – with AB, osteoplasty, and mechanical decontamination of the implant + antiseptic [AB+/AS+]; Group 2 – with AB and mechanical decontamination of the implant with saline solution + osteoplasty [AB+/AS-]; Group 3 – without AB, with osteoplasty + implant decontamination with antiseptic [AB-/AS+]; Group 4 – without AB and antiseptic, with osteoplasty + implant decontamination with saline solution [AB-/AS-].

The surgical operation consisted of eliminating the pockets with a bone resection technique (bone regularization) performed by five experienced periodontologists. The implants were of different brands, and it was observed that the texture of the implants was different (modified versus unmodified [Mod-/Mod+]).

The results showed that, on average, there was a reduction of 2.73±2.39 mm of PD and a bone loss of 0.04±1.64 mm. The proportion of implants presenting with BoP/SoP+ was reduced by 40%; the predicted probability of BoP/SoP+ at 3 years was lower for implants with non-modified surfaces (ranging from 27% to 44%) than modified surface implants (70%); systemic antibiotics had no effect in terms of BoP/SoP. The average BoP around the implants, after one year, went from 33.1% to 60.3% after 3 years (AB^+: 32.4% → 66.2%; AB^-: 34% → 52.8%; Mod^+: 38.9% → 70%, and Mod^-: 16.1% → 32.3%).

Papadopulos et al. (2015)

This study aimed to compare the treatment of PI between the simple resective surgery technique (Osteoplasty) and the supplementary addition of diode laser in resective surgery. For this purpose, 19 patients (12 women and 7 men) with a mean age of 55 years were treated; 10 were placed in group C (placebo group) and 9 in group L (test group). The treatment had a follow-up of 6 months; patients were monitored at t=0, months, and 6 months. The patients were randomly allocated to the groups.

Treatment for group C: the mechanical debridement with ultrasound was performed before treatment and after four weeks post-operative. Local anesthesia was applied, and the patient had to rinse with CHX 0.2% before the procedure. Full-thickness flaps were used to access the peri-implant bone defects using the "open flap" technique. Granulation tissue was removed from the implant surface with plastic curettes. The implant surface was carefully cleaned with NaCl.

The same procedure was performed in group L, except that diode laser treatment was added after cleaning the implant with cotton. A low-intensity laser (980nm) was used to disinfect the implant. A 0.8W pulsed laser irradiation was used on the exposed implant surface with NaCl irrigation. Each affected surface was treated three times with a 2-minute interval. After the intervention, the flaps were sutured, and oral hygiene instructions were given to the patients, and they were recommended to rinse their mouths twice a day with CHX 0.12%. The sutures were removed 14 days after the intervention.

The results were presented as follows: the initial mean PD in the test group was 5.92 mm; after treatment, it showed a decrease of 1.38 mm (4.44 mm). In the control group, the initial mean PD was 5.52 mm and showed a decrease of 1.19 mm after treatment, obtaining 4.31 mm. The BoP in the test group went from 93.5% to 31.3%, whereas in the control group, a reduction of 66.7% was presented; the results went from 81.2% initially to 23.8% at the end of the treatment. The authors concluded that surgical treatment of peri-implantitis by access flaps improves all clinical parameters studied, while the additional diode laser did not seem to have an extra beneficial effect.

Discussion

PI can be considered a worldly emerging problem in oral health. Several surgical and non-surgical approaches have been identified and reported in the literature, trying to solve this disease [1]. However, its predictability and long-term therapeutic efficacy remain controversial, with little scientific evidence to support a therapy with high efficacy and predictability. Given the heterogeneity of the studies included in the present study, the patient's characteristics, the techniques used, and the evaluation methods, comparing the different approaches becomes extremely difficult [18].

The effects of antibiotics (antimicrobials) during resective surgical intervention have shown positive results at the beginning of treatment, but in the long term, these are not observed [20,22]. An optimization of clinical and microbial parameters is demonstrated in studies that advocate osteoplasty techniques with/without the addition of antimicrobials. A great improvement in BoP results was demonstrated with the implantoplasty technique. The disinfection techniques used with laser, antibiotic (AB), chlorohexidine (CHX), or CPC demonstrated positive results but did not show significantly different results between them. These results show that they are simple and effective techniques and that they can be used in the resective surgical treatment of PI.

The best PD reduction result obtained was found in Bianchini et al.. 's study [24], with a 75% PD decrease; this fact can be explained by the reduction in bacterial adhesion to the implant surface after implantoplasty [1]. In DeWaals et al.'s study [20], there was a 44.7% decrease in the PD percentage; similar result was found on DeWaals et al. [22], with an average value of 40.7%. In the Hentenar et al.'s study [23], a 43.6% decrease was observed, compared to 38% decrease reported by Englezos et al.'s article. Carcuac et al.'s [26] and Papadopoulos et al.'s [27] studies presented equivalent results, indicating a 25% decrease in PD, which can be explained by the similarity of the therapeutic approach used in both studies (osteoplasty and addition of antibacterial agents).

Regarding BoP, the best result in the %BoP reduction was present by Papadopoulos et al. [27], with an average reduction of 73% and 67%, respectively, approaching PI with an isolated "open flap" debridement and adding laser. The application of laser in the treatment may have contributed positively to decontamination and reduction of inflammation [28,29], thus demonstrating a reduction in BoP. De Waals et al. [20] showed 61% of reduction; de Waals et al. [22] had a 40% reduction, and Hentenar et al. [23] presented a 57% BoP difference using phosphoric acid. The study approaching PI with implantoplasty [24] showed a 71% BoP difference, which was the second-best result for this clinical parameter (implantoplasty favored the decrease in bacterial adhesion). Otherwise, Carcuac et al. [26] presented an increase of almost 30%; this was the worst result obtained in this review for the clinical parameter discussed.

The last parameter studied in this review was the MBL difference. The best result for this parameter was obtained by Englezos et al. [25], with a difference of 4.9 mm. In the study by de Waals et al. [20], the authors observed a difference of 0.7 mm, which is similar as the result obtained by Bianchini et al. [24], with a difference of 0.65 mm. De Waals et al. [22] observed a difference of 0.3 mm; Carcuac et al. [26] observed a difference of 0.04 mm.

The difference found for results between authors (Bianchini et al. [24] and Englezos et al. [25]) using the same technique can be explained by the follow-up, which was 1 year. The number of patients and age may be confounder factors to take into account in the results. In this review, the number of patients varied in each study included and can be considered relatively small in some studies; this fact can be translated into a lower expression in a study with a smaller sample compared to a study with a larger sample.

Table 1. Data retrieved.

Article	Year	Implant surface	Protocol	n and Mean age	Follow-up (months)	Mean Probing Depth (PD)	Mean %BoP (Bleeding on Probing)	Mean Marginal Bone Loss (MBL) (mm)	Conclusion
deWaal et al.	2013	79 Treated surface	Resective surgery with osteoplasty and surface debridement Group 1: 0.12% CHX + 0.05% CPC Group 2: placebo	30 patients: Group 1: 15 61.5 years Group 2: 15 59.4 years	12	Mean PD > 5mm: Group 1: - Initial: 88.2% - Final: 33.9% Group 2: - Initial: 75.2% - Final: 17.1% Mean PD > 6mm: Group 1: - Initial: 54.4% - Final: 17.7% Group 2: - Initial: 46.9% - Final: 17.2%	Group 1: - Initial: 87.1% - Final: 25.8% Group 2: - Initial: 81.3% - Final: 15.8%	Group 1: - Initial: 4.3 - Final: 5.0 Group 2: - Initial: 3.6 - Final: 3.9	PD, BoP and radiographic MBL parameters improved in both groups, but without significant differences between them
deWaal et al.	2015	108 Treated surface	Resective surgery with osteoplasty and debridement of the surface Group 1: CHX 0.2% Group 2: 0.12% + 0.05% CPC	44 patients Group 1: 22 60.5 years Grupo 2: 22 58.6 years	12	Mean PD > 5mm: Group 1: - Initial: 57.5% - Final: 7.3% Group 2: - Initial: 60.2% - Final: 7.3% Mean PD > 6mm: Group 1: - Inicial: 29.1% - Final: 2.1% Group 2: - Initial: 34.4% - Final: 1.4%	Group 1: - Initial: 82.1% - Final: 42.7% Group 2: - Initial: 74.2% - Final: 37%	Group 1: - Initial: 4.0 - Final: 4.3 Group 2: - Initial: 4.1 - Final: 4.1	PD, BoP, and radiographic MBL parameters improved in both groups, but without significant differences between them
Hentenar et al.	2017	53 Not reported	Resective surgery with osteoplasty and debridement of the surface Group 1: phosphoric acid 35% Group 2: Saline solution	28 patients Group 1: 14 57 years Group 2: 14 60.9 years	3	Mean PD > 5mm: Group 1: - Initial: 67.1% - Final: 17.8% Group 2: - Initial: 61.3% - Final: 18.3% Mean PD > 6mm: Group 1: - Initial: 50% - Final: 12.5% Group 2: - Initial: 46.8% - Final: 12.2%	Group 1: - Initial: 86.4% - Final: 28.8% Group 2: - Initial: 66.1% - Final: 39.2%	Not reported	Clinical parameters (PPD, BoP) improved in both groups, but without significant differences between them. Clinical parameters (PD, BoP) improved in both groups, but without significant differences between them
Bianchini et al.	2020	Not reported	Resective surgery with osteoplasty and debridement of the surface Implantoplasty	4 patients (2 men and 2 women) 53 years	36	- Initial: 6.0mm - Final: 1..5mm Difference: 4.75mm	- Initial: 83% - Final: 12% Difference: 71%	Mesial (M): - Initial: 4.8mm - Final: 4.0mm Distal (D): - Initial: 5.0mm	Implantoplasty surgery revealed a significant decrease in clinical and radiographic parameters. It can be considered as a

						Absence of pain and suppuration at the end of follow-up		- Final: 4.5mm Difference: 0.8 (M) 0.5 (D)	viable treatment for peri-implantitis
Carcuac et al.	2017	121 implants Different types of surfaces	Four techniques: - Osteoplasty - Osteoplasty + systemic antibiotic - Osteoplasty + antiseptic solution - Osteoplasty + antiseptic solution + systemic antibiotic	67 patients 66.3 years	36	Mean PD: -2.73mm in all implants AB^+ : -3,0mm AB^- : -2,38mm Mod^+ : -2,67mm Mod $^-$: -2,90mm	After - 1 year: 33.1% - 3 years: 60.3% AB^+ 32,4 → 66 AB^- 34% → 52,8 Mod^+ 39% → 70% Mod^- 16% → 32%	-0.04 mm in all implants AB^+ 0.32mm AB^- -0.51mm Mod^+ -0.28mm Mod^- 0.65mm	Resective surgical treatment of peri-implantitis with osteoplasty had good results, but it seems that the results are dependent on the roughness of the implant
Englezos et al.	2018	40 implants Different types of surfaces and brands	Full-thickness flap, osteoplasty, debridement of the implant, implantoplasty, CHX, and NaCl	25 patients 66.2 years	24	Mean PD: - Initial: 8.7mm - Final: 5.4mm	Not reported	- Initial: 5.1mm - Final 0.2mm	Efficacy of peri-implantitis treatment with resective surgery added to implantoplasty. A good bacterial plaque control must be performed by the patient
Papadopoulos et al.[27]	2015	Not reported	Group 1: Open flap debridement Group 2: Open flap debridement with laser adjunct for the treatment of peri-implantitis	16 patients Group 1: 8 Group 2: 8 50 years	6	Group 1: - PD initial: 5.92 mm - After treatment: 4.44 mm → reduction 1.38 mm Group 2: - PD initial: 5.52 mm - After treatment: 4.31 mm → reduction 1.19 mm	Group 1: - Initial 93.5% - After treatment 31.3% → reduction of 72.9% Grupo 2: - Initial 81.2% - After treatment 23.8% → Reduction of 66.7% ($p < 0.05$)	Not reported	Surgical treatment of peri-implantitis with “open flap” access shows a decrease in the results of clinical parameters, but the addition of laser did not increase its effectiveness

The different numbers of patients and the lack of homogeneity in the group's gender—never 50% male and 50% female or the same number of each gender—may contribute to limitations and influence the disparities in results between the studies. The difference in results between the same techniques can be explained by the discrepancies between the protocols of the different authors; it is possible to consider possible differences in professional experience. The treatment length was also important in describing the results, and this difference may translate into a limitation of the results. In addition, the number of implants treated in each study can also be considered a limitation; a high number of implants (121 in Carcuac et al.'s study [26]) and a low number of implants [n=40] in Englezos et al.'s study [25]) may lead to a probability of obtaining results with discrepant values.

Radiographic examinations evaluated the bone contours, measuring the distance from the implant platform to the bone crest. AB or disinfectant reduced bone loss and improved its stability. The addition of chemicals or lasers did not significantly differ in clinical parameters compared to manual debridement techniques. However, implantoplasty, as Martins et al. [1] reported, showed a statistically significant difference compared to the other techniques. It had better results in both clinical and radiographic parameters.

Regardless of the simplicity of the resective surgical technique, it depends on several parameters, such as the patient's accessibility to oral hygiene care and the follow-up recommended by the operator. However, Carcuac et al. [26] found that the dental implant surface roughness may influence the results.

The disinfection protocol is not crucial to the success of the treatment (placebo treatment versus CHX treatment). The postoperative maintenance protocol can support the variability in treatment success. In this review, a reduction in inflammation and bone loss was desirable for PI treatment. Therefore, it is possible to agree with Klinge et al.'s study [30], which explained that PI treatment has beneficial effects but that implant debridement alone has a limited impact on the treatment. In the implant debridement approach, it is recommended to use titanium curettes to avoid damage to the implant surface and perform surgical debridement during resective surgical treatment [31]. Decontaminating the implant and tissue remodeling provides a favorable anatomy to bone regeneration. The combination of mechanical and chemical treatments gives better results, as explained in Mellado-Valero et al. [3].

All the articles here included the pre-and post-operative protocols, and their results showed that, in terms of duration, there was no significant effect before 6 months of treatment. To be sure that the antibiotic had a beneficial impact on the resective surgical treatment of PI, it is necessary to carry out more randomized clinical trials with protocols using AB in addition to mechanical debridement of the implant. Romeo et al. [33] demonstrated the difference between implantoplasty (IP) and isolated resective surgery. IP showed more advantages in terms of bone preservation; other studies compared IP: the comparison between Er: YAG laser and saline solution, resulting in improvement of biological and clinical parameters in both techniques [34].

With the results of this integrative review, it is possible to support better surgical treatment of PI, where implantoplasty was more effective in cases of severe PI. However, persistent disease can cause implant mobility, and in this case, the procedure will follow for explantation of the implant and regenerative therapy. A therapeutic plan of reassessment should then be planned to remove excess bacterial plaque and calculus and perform total disinfection to reduce the likelihood of the disease present. Serino et al. [35] showed that patients with good oral hygiene and professional re-evaluation every 6 months improved treatment stability over 5 years.

Conclusion

The results obtained for resective surgical techniques (osteoplasty and/or osteotomy), with or without antimicrobial treatment, showed significant improvement in the medium- and long-term clinical parameters. Implantoplasty in resective surgical procedures contributed to a significant reduction in bleeding, suppuration, and decreased depth of the pockets present; moreover, it has shown satisfactory clinical and radiological results compared to isolated mechanical debridement techniques. Support therapy, regardless of the addition of different techniques, positively impacted the prevention of PI, with follow-up and patient compliance/cooperation being essential factors in obtaining better results.

All techniques studied and described in this integrative review positively impacted the observed clinical parameters, showing decreased PD, BoP, MBL, and SoP in implants affected by PI. In this sense, the need to carry out more clinical, randomized, and controlled studies became evident, with a larger sample, longer follow-up, and a more standardized protocol made it possible to compare and determine the best surgical resective therapeutic approach for PI.

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