



PERI-IMPLANTITIS: IDENTIFICATION OF RISK FACTORS AND TREATMENT PROTOCOLS – PART II

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ABSTRACT

This article delves into the surgical treatment strategies for peri-implantitis, an inflammatory condition affecting the tissues around dental implants. It emphasizes that while non-surgical therapy can be effective in the early stages, surgical intervention often becomes indispensable to halt the progression of the pathology. The article reviews various surgical approaches, including resective surgery, regenerative surgery, mechanical decontamination, laser treatments, antibiotic therapy, electrolytic cleaning, and implantoplasty. Resective surgery aims to reduce the depth of peri-implant pockets through resection of inflamed soft tissue and bone remodeling, while regenerative surgery aims to reconstruct lost bone tissue using bone biomaterials, barrier membranes, and biological factors. Mechanical decontamination involves removing biofilm and mineralized deposits from the implant surface, while laser treatments and electrolytic cleaning offer alternative methods for decontamination. Antibiotic therapy, both systemic and topical, is sometimes used as a support to mechanical decontamination. Finally, implantoplasty involves removing implant threads and smoothing the exposed surface to reduce biofilm accumulation. The article highlights the importance of appropriate selection of the surgical strategy based on the patient's characteristics, the severity of the bone damage, and the risk factors present. It further emphasizes the need for a multidisciplinary approach that integrates surgical therapies with non-surgical treatments and careful follow-up management to ensure the success of peri-implantitis treatment and the durability of dental implants. The article concludes by highlighting the need for further research to refine surgical techniques, develop new biomaterials, and evaluate the effectiveness of emerging therapies, with the aim of improving clinical outcomes and the quality of life of individuals affected by peri-implantitis.

KEYWORDS: *Peri-implantitis, surgical treatment, regenerative surgery, mechanical decontamination, laser therapy*

INTRODUCTION

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Peri-implantitis is an inflammatory condition that affects the hard and soft tissues around dental implants. This condition, increasingly common in dentistry, can severely compromise the longevity of implants and the overall oral health of the patient (1). It manifests with loss of supporting bone, swelling, bleeding, and, sometimes, pus formation, making prompt and targeted therapeutic intervention essential (2). The etiology of peri-implantitis is multifactorial, with a primary role played by the accumulation of bacterial biofilm on the implant surface, which triggers a dysfunctional immune response in the host. Fundamental is also the role of mast cells and neuropeptides. The activation of mast cells by neuropeptides can influence the inflammatory microenvironment through the modulation of cytokines, and thus potentially contribute to the pathogenesis of peri-implantitis (3). Histologically, peri-implant lesions are distinguished by a more extensive inflammatory infiltration and deeper bone destruction compared to periodontal lesions. Risk factors such as poorly controlled diabetes, smoking, previous periodontitis, genetic predispositions, and biomechanical or prosthetic factors—such as inadequate occlusions and unfavorable prosthetic emergencies—significantly contribute to the onset and progression of the disease (4). The management of peri-implantitis is complex and must be personalized based on the severity of the disease, the characteristics of the patient, and specific risk factors. A correct diagnosis and evaluation of the patient are essential for planning an effective treatment of peri-implantitis and minimizing risks. This process must include a comprehensive medical history, not only of local and environmental risk factors but also of the patient's medical and family conditions. Although rare, some genetic conditions that affect bone development, such as cleidocranial dysplasia associated with mutations in the CBFA1/RUNX2 gene, can impact oral health and the bone's ability to support dental implants. Therefore, including a detailed family and medical history can help identify at-risk patients and customize the treatment plan to maximize long-term success (5). Treatment options range from non-surgical therapies, focused on the mechanical and chemical decontamination of the implant surface, to surgical interventions. The latter include resective, regenerative approaches, and implantoplasty (6). This article aims to explore in detail the various surgical treatment strategies for peri-implantitis, analyzing the indications, techniques, and clinical outcomes associated with each method. Through an in-depth analysis of the most recent scientific literature and clinical guidelines, this work aims to provide a comprehensive and up-to-date overview of the surgical options available for the management of peri-implantitis. The aim is to provide clinicians with evidence-based decision support to improve therapeutic outcomes and long-term prognosis for their patients.

SURGICAL THERAPY

Although non-surgical therapy can be effective in the early stages of the disease (mild peri-implantitis), surgical treatment often proves indispensable to halt the progression of the pathology and promote the recovery of peri-implant tissues (7). The reasons for this necessity are manifold: the morphological complexity of peri-implant pockets, the difficulty of access for cleaning, the particular nature of the implant surface that promotes bacterial adhesion, and the presence of deeper bone defects (8). Surgical treatment allows direct access to the implant surface to remove inflammatory tissues and bacterial contamination, modify the bone morphology to facilitate home hygiene, and, in selected cases, regenerate lost bone tissue (9). The scientific literature of the last 10 years has consolidated two fundamental surgical approaches: resective surgery and regenerative surgery, the choice of which depends on the type and severity of the bone defect, as well as local and systemic factors that can influence the prognosis (10).

Resective Surgery

Resective surgery aims to reduce the depth of peri-implant pockets through the resection of inflamed soft tissue and the remodeling of peri-implant bone, with the goal of facilitating plaque removal and maintaining a more favorable biological environment (8). This technique is particularly indicated for bone defects with unfavorable geometry, such as horizontal or saucer-shaped defects, where bone regeneration is unpredictable or impossible (11). Numerous clinical studies have reported encouraging data: in a systematic review of 12 studies with follow-up from 1 to 5 years, resective surgery showed an average reduction in probing depths of 3.1 mm, a decrease in bleeding on probing (BOP) of over 70%, and stability in bone loss in over 80% of cases (12). A randomized trial involving 58 patients showed a significant improvement in probing depth from 6.4 mm to 3.2 mm at 12 months, accompanied by an improvement in peri-implant soft tissue (13). The decontamination of the implant surface is a crucial step in this protocol. It has been demonstrated that mechanical decontamination alone is not always sufficient: therefore, multiple methods are combined, including ultrasonic scalers with titanium tips, Er:YAG or CO₂ lasers, and chemical agents such as sodium hypochlorite, chlorhexidine, and hydrogen peroxide (14). Recent studies indicate that the use of the Er:YAG laser, in conjunction with resective surgery, significantly improves the reduction of bacterial load and promotes better clinical stability. The EFP 2022 guidelines suggest resective surgery as the treatment of choice for shallow (<3 mm) and horizontal bone defects, especially in the presence of an adequate amount of keratinized soft tissue (15). However, it is essential to consider the

aesthetic limitations of this technique, especially in anterior sectors, where the reduction of soft tissue can lead to mucosal recessions and aesthetic alterations (12). The management of soft tissue is crucial, with techniques to increase the volume of keratinized mucosa to improve site stability and prevent recurrences (16,17). Moreover, smoking patients or those with poor oral hygiene present a higher risk of long-term failure.

Regenerative Surgery

Regenerative surgery aims to reconstruct lost bone tissue through the use of bone biomaterials, barrier membranes, and biological factors that stimulate tissue regeneration (18). It is indicated for contained bone defects, such as those with three or four walls or deep vertical defects (≥ 4 mm), where the morphology allows for the containment of the graft material and the formation of a stable clot (10). Clinical evidence supports a significant improvement in clinical and radiographic parameters with regenerative surgery. A meta-analysis of 14 clinical studies found an average reduction in probing depth of 3.8 mm and a radiographic bone gain between 2.5 and 4.2 mm at 12-24 months, with an improvement in BOP of over 60% (14). More recent studies have also highlighted how the addition of platelet-derived growth factors (PRF, PRP) enhances bone regeneration and clinical stability over time (19). The therapeutic protocol involves the complete removal of infected tissue, decontamination of the implant surface, placement of autologous, allogeneic, or synthetic bone grafts, and the use of resorbable or non-resorbable membranes to guide regeneration (20). The management of soft tissue is crucial, with techniques to increase the volume of keratinized mucosa to improve site stability and prevent recurrences

(12). A large multicenter study on 85 implants treated with regenerative surgery showed clinical success (pockets ≤ 4 mm and absence of BOP) in 82% of cases at 2 years, compared to 58% in the group treated with resective surgery (19). These data confirm the effectiveness of regenerative surgery in selected patients and underscore the importance of proper clinical indication. The EFP 2022 guidelines recommend regenerative surgery for deep defects (≥ 4 mm) with adequate presence of keratinized soft tissue, while emphasizing the need for long-term monitoring and careful management of systemic risk factors (smoking, diabetes) to prevent recurrences (15).

MECHANICAL TREATMENT OF PERI-IMPLANTITIS

Scaling and Mechanical Decontamination

Scaling and mechanical decontamination represent the first recommended therapeutic approach in the management of peri-implantitis, especially in the early stages or as a stabilization treatment in advanced clinical cases. The objective of this intervention is the effective removal of biofilm and mineralized deposits present on the implant surface, responsible for chronic inflammation and progressive bone loss (21). According to the guidelines of the European Federation of Periodontology (EFP), professional scaling performed with mechanical instruments is indicated as a first-line treatment in all diagnosed cases of mucositis and mild-moderate peri-implantitis (22). The most commonly used instruments include curettes made of reinforced plastic or titanium, sonic or ultrasonic inserts with coated tips, and rotary brushes, which allow access to the rough surfaces of implants without damaging them (23). The effectiveness of these instruments has been evaluated in numerous controlled clinical studies: For example, a randomized study conducted by Louropoulou (24) demonstrated that the removal of biofilm with titanium curettes allows for a significant reduction in probing depth (from 5.4 mm to 3.9 mm on average) and bleeding on probing (from 84% to 36%) after 3 months of treatment. Recent *in vitro* analyses have confirmed the effectiveness of ultrasonic scaling techniques and air-abrasive powders on different surfaces of implants and prosthetic components, highlighting significant differences in decontamination capacity depending on the material and surface topography (25). Implants with a rough surface present greater difficulties in the complete removal of biofilm due to increased bacterial adhesion. Despite this, an *in vivo* study conducted by Toma et al. showed that the repeated use of mechanical decontamination in a 6-month follow-up maintains a significant reduction in peri-implant inflammation when associated with regular maintenance recalls (26). In terms of clinical outcomes, mechanical debridement alone has been shown to achieve an average reduction in pocket depth ranging from 0.5 mm to 1.3 mm, with significant improvements in bleeding and plaque (27). However, the long-term success rate varies significantly depending on patient compliance and the frequency of professional recalls: a 3-year longitudinal study conducted by Carcuac et al. found that only 39% of sites treated exclusively with mechanical decontamination maintained clinical stability without further bone loss, highlighting the need for intensive monitoring (28). In this context, the integration of biocompatible regenerative approaches, such as the use of Platelet-Rich Fibrin (PRF), can represent a valuable support in the management of inflamed soft tissues, promoting tissue healing and reducing symptoms, as demonstrated in the treatment of oral mucositis in oncological patients (29). Finally, it should be emphasized that mechanical scaling, although less invasive than surgical treatments, requires precision, repetition, and appropriate instrumentation to be effective. Its effectiveness is greatly enhanced by the patient's motivation and strict adherence to personalized hygienic-professional

maintenance protocols. It thus represents an essential pillar in the management of peri-implant diseases, both as an initial treatment and as long-term supportive therapy.

TREATMENT OF PERI-IMPLANTITIS USING LASER TECHNIQUES

The use of lasers in the treatment of peri-implantitis has received increasing attention in recent years, thanks to their ability to deeply decontaminate the implant surface, reduce inflammation, and promote tissue healing, all with a minimally invasive approach (30). The main devices used in clinical settings include Nd:YAG, Er:YAG, CO₂, and diode lasers, each with specific absorption and penetration characteristics in soft and hard tissues (31). One of the main advantages of lasers is their ability to eliminate biofilm and granulation tissue without causing permanent microstructural alterations to the implant surface (32). According to a randomized controlled trial by Schwarz et al, the use of the Er:YAG laser in open surgery resulted in an average reduction of pocket depth by 2.4 mm and a radiographic bone gain of 1.2 mm after 6 months, results comparable to or superior to those obtained with conventional mechanical decontamination (33). Moreover, laser treatment has proven effective in significantly reducing probing bleeding and inflammatory infiltrate, without the need for direct contact with the implant surface. Another systematic review conducted by Panda et al. analyzed 12 randomized clinical studies and highlighted that the use of lasers, particularly Er:YAG and Nd:YAG, significantly improves periodontal indices compared to mechanical treatment alone (34). However, the authors emphasize that effectiveness is highly dependent on the operational parameters used, such as wavelength, power, and duration of exposure, as well as the type of laser employed. An important aspect to consider concerns post-treatment biocompatibility: An *in vitro* study conducted by Aoki et al. demonstrated that irradiation with Er:YAG laser, set to clinically acceptable parameters, does not compromise the adhesion of osteoblastic cells to the implant surface, but rather promotes their recolonization (35). Even the diode laser, although less powerful in ablative terms, has proven useful as an adjunct for controlling infection and bacterial load in deep pockets, as evidenced by Ramanauskaite et al. in a clinical trial conducted on 36 patients. (36). Finally, recent guidelines published by the European Association for Osseointegration (EAO) recommend the use of lasers as an adjunctive therapeutic option in the early or moderate stages of peri-implantitis, especially when there are contraindications to surgery. However, it is specified that the effectiveness of the laser, although supported by encouraging data, does not yet have sufficient evidence to completely replace surgical protocols in advanced cases (37).

ANTIBIOTIC THERAPY

The use of antibiotics, both systemic and topical, represents a consolidated and often used strategy as support for mechanical decontamination in cases of peri-implantitis with acute infections or deep pockets (>5 mm). However, isolated systemic antibiotic therapy is not recommended, as emphasized by the guidelines of the European Federation of Periodontology (EFP, 2022). In a randomized controlled study involving 37 patients who received amoxicillin (375 mg) in combination with metronidazole (250 mg) for 7 days, combined with mechanical decontamination, the mean probing depth decreased by 2.28 mm compared to 1.47 mm in the group receiving only mechanical therapy. However, the bleeding on probing rate remained high (≈81%), suggesting a partially limited clinical benefit over time (38). A similar study conducted by De Waal et al. on 62 patients showed that the systemic addition of amoxicillin/metronidazole did not bring about significant clinical or microbiological improvements compared to mechanical decontamination alone at 3 months, indicating the need to reduce the use of systemic antibiotics as a therapeutic adjunct (39). Conversely, studies on topical antibiotics have reported more encouraging results. A multicenter clinical trial evaluated the local application of 2% minocycline gel, administered weekly for 4 weeks in addition to mechanical debridement. After 6 months, a significant reduction in probing depth (−1.8 mm) and a decrease in bleeding on probing (−47%) were recorded compared to the control group (40). Another study by Carcuac et al. confirmed that topical minocycline administered during the surgical phase led to clinical improvement and radiographic stabilization in 66.7% of cases, compared to 36.3% in the group without local antibiotic (41). In this context, the use of anti-inflammatory drugs could also play an important role. Studies have explored the incorporation of anti-inflammatory drugs into polymeric nanohybrids for localized controlled release. This approach could allow for targeted drug release, potentially reducing systemic side effects and maximizing local efficacy in modulating inflammation and promoting the healing of peri-implant tissues. Further research is necessary to evaluate the clinical efficacy of these strategies (42).

Finally, a meta-analysis of 5 randomized studies has shown that the systemic use of amoxicillin with metronidazole does not result in significant differences in probing depth at 3 and 6 months but shows a significant improvement in bleeding on probing and bone level at 12 months (43). Systemic antibiotic therapy may offer a modest and short-term clinical benefit and should be used with caution due to the risk of bacterial resistance. Topical therapy, particularly with

minocycline gel, seems to offer more stable and specific results in managing bacterial load and peri-implant inflammation. However, the support of mechanical decontamination remains fundamental and indispensable.

ELECTROLYTIC CLEANING

Electrolytic cleaning is an emerging technique that presents itself as a minimally invasive and highly effective method for the decontamination of implant surfaces in cases of peri-implantitis. This technology, based on the application of low-intensity electric current in the presence of an electrolyte, promotes the selective removal of the bacterial biofilm without altering the microtopography of the implant (44,45) thereby preserving the macro- and nanostructural features (46). *In vitro* study has demonstrated that applying ± 3 V for 5 minutes on contaminated implants results in a reduction of bacterial load from approximately 3.15×10^6 to 2.9×10^4 CFU/mL, showing superiority over lower voltages (44). This suggests a significant clinical potential in biofilm removal. In a 24-month randomized clinical trial, electrolytic cleaning (EC) was compared with a combined approach of air-water abrasion + electrolysis (PEC) in surgical contexts. After 6 months, both modalities showed similar bone gain (EC: 2.7 mm; PEC: 2.8 mm), with a peri-implant healing rate of 91% in the EC group, demonstrating the clinical applicability of electrolytic cleaning alone (47). The 18-month follow-up data conducted by the same group showed that approximately 50% of the implants subjected to electrolytic cleaning exhibited complete bone reintegration, without the need for further invasive procedures (48). Finally, a pilot *in vitro* study compared electrolytic cleaning with mechanical methods (toothbrushes and erythritol jets), showing similar efficacy in decontamination but a notable advantage in preserving the implant microstructure, a crucial aspect for long-term osseointegration (45). Several studies have demonstrated the crucial role of mast cells (3), cytokines (IL-33, IL-1 β , etc.) (49), and drugs (50) in oral and intestinal inflammation (51), soft and hard tissue necrosis (50,51), allograft rejection (52,53) and cancer development (53), and the potential role of laser technology in their therapy (54). In summary, electrolytic cleaning proves to be a promising methodology for halting the progression of peri-implantitis, with bone gains between 2.7–2.8 mm in trials and a high healing rate (>90%). These results, combined with the preservation of implant microtopography, make it an effective and safe option: further clinical studies are still necessary to consolidate its routine use.

IMPLANTOPLASTY

Implantoplasty is a surgical procedure aimed at removing implant threads and smoothing the exposed surface to reduce biofilm accumulation and facilitate post-treatment cleaning. A systematic review conducted by Esteves Lima et al. reported that implantoplasty, integrated into surgical treatment protocols, allows for an implant survival rate of 94–97% at one or more years, with significant clinical improvements in terms of probing depth (PD) and bleeding on probing (BOP) (55). A randomized prospective clinical study on 33 implants compared implantoplasty plus mechanical debridement vs. debridement alone. While observing temporal improvements in both groups, no statistically significant difference was found in the PD, PI, and BOP parameters at 24 months, suggesting that the additional effectiveness of implantoplasty might be modest (56). From a biomechanical perspective, an *in vitro* study with finite element analysis has shown that implantoplasty reduces the fracture resistance of implants with 5 mm of bone loss, while implants with only 3 mm of bone loss did not show significant variations (57). This indicates that the procedure can alter structural integrity when the supporting bone is already compromised. In an *in situ* clinical trial, a significant reduction in biofilm accumulation was observed on surfaces treated with implantoplasty, decreasing from 65% biofilm coverage to 16% compared to untreated implants, confirming the utility of polishing in controlling recolonization (58). A 2022 meta-analysis compared implants subjected to implantoplasty in regenerative vs non-regenerative contexts, finding better bone gains when the procedure was integrated into regenerative protocols, although no significant differences were noted in PD or BOP parameters between groups (59). Implantoplasty improves the manageability of the implant and reduces bacterial accumulation, with proven effectiveness in clinical stabilization: The data indicate high survival rates (>94%) and greater bone gains in regenerative approaches. However, it is essential to carefully assess the decrease in structural strength, particularly in cases with advanced bone loss (>5 mm) (60,61). This procedure can be particularly advantageous in immediate post-extraction implants to ensure healing and long-term maintenance (62).

CONCLUSIONS

Peri-implantitis remains a significant issue in contemporary dentistry, necessitating an integrated and personalized therapeutic approach. Although non-surgical strategies are a cornerstone in the initial phase and long-term maintenance, surgical procedures prove essential for addressing advanced bone lesions and restoring the health of peri-implant tissues. Furthermore, in the future, better understanding of how age-related changes influence tissue response to peri-implantitis

could lead to more personalized treatments. In this perspective, the study of age-related molecular alterations in tissues can provide valuable insights into the biology of ageing and its influence on the host's response to peri-implantitis (63), highlighting the importance of interdisciplinary research and the application of molecular biology techniques in the study and treatment of this pathology (64). The selection of the most appropriate surgical strategy must be

based on a careful analysis of the patient's characteristics, the severity of the bone damage, and the present risk factors. A multidisciplinary approach, which integrates surgical therapies with non-surgical ones and careful follow-up management, is essential to ensure the success of peri-implantitis treatment and the durability of dental implants. Further investigations are desirable to refine surgical techniques, develop new biomaterials, and evaluate the effectiveness of emerging therapies, with the aim of improving clinical outcomes and the quality of life for individuals affected by peri-implantitis.

Conflict of interest

The authors declare that they have no conflict of interest.

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