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Peri-Implantitis Management Strategies: A Comprehensive Review of Regenerative, Pharmacological, and Surgical Interventions

Dr. Mohammad Jalaluddin[1]*, Dr. Bennete Fernandes[2], Dr. Monisha Sugumaran. S[3], Dr. Amita Olivia Coutinho[4], Dr. Khushboo Rastogi[5], Dr. Nasser Imdadulla[6]

[1]*Professor and Head, Department of Periodontics and Implantology, Kalinga Institute of Dental Sciences (KIDS), KIIT University, Bhubaneswar, Odisha, India

[2]Faculty of Dentistry, SEGi University, Selangor-47810, Malaysia and Adjunct Professor, Department of Periodontology, Dr. D.Y.Patil Dental College & Hospital, Dr. D.Y Patil Vidyapeeth, Pimpri, Pune-411018, Maharashtra, India

[3]3rd Year Post Graduate, Department of Periodontology, Sri Venkateshwaraa Dental College, Villupuram Main Road, Ariyur, Puducherry - 605102, India

[4]Reader, Department of Periodontics and Implantology, The Oxford Dental College, Bommanahalli, Bangalore, Karnataka – 560068, India

[5]Professor and Head, Periodontist and Public Health Specialist, Saraswathi Institute of Medical Sciences, Anwarpur, Hapur, Uttar Pradesh - 245304, India

[6]3rd Year Post Graduate, Department of Periodontology, Chettinad Dental College and Research Institute, Chennai, Tamil Nadu - 603112, India

***Corresponding Author:**

Dr. Mohammad Jalaluddin

Professor and Head, Department of Periodontics and Implantology, Kalinga Institute of Dental Sciences (KIDS), KIIT University, Bhubaneswar, Odisha, India

Email ID: drjalal1979@gmail.com

ABSTRACT

Peri-implantitis is an inflammatory condition affecting the hard and soft tissues surrounding dental implants, leading to progressive bone loss and eventual implant failure. The management of peri-implantitis requires multimodal strategies that integrate antibacterial, regenerative, and host-modulating approaches. Emerging innovations such as bioengineered implants, targeted drug delivery, and host modulation not only enhance patient outcomes and implant longevity (SDG 3) but also emphasize the need for continuous professional education (SDG 4). Advancing this field further depends on global research collaboration and interdisciplinary partnerships (SDG 17) to translate innovation into universally applicable clinical protocols. The present review highlighted peri- implantitis management strategies.

Keywords: *Peri-implantitis, Regenerative, Flap, SDG Goals 3,4,17*

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1. INTRODUCTION

Peri-implantitis is an inflammatory condition affecting the hard and soft tissues surrounding dental implants, leading to progressive bone loss and eventual implant failure. The biological difficulties associated with dental implants are growing as a result of the growing number of implants that are placed daily in clinical practice. These issues include significant peri-implant bone resorption, implant failure, and inflammation and bleeding upon probing (BOP) [1].[1] There is currently no widely accepted methodology to successfully and predictably resolve these issues, despite numerous studies targeted at

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determining the best way to treat these disorders. There are two categories of procedures available to clinicians: non-surgical and surgical. Regenerative and restorative treatments are the two primary surgical possibilities.

2. TREATMENT STRATEGIES

1. **Non-Surgical Therapy**:
   - **Mechanical Debridement:** Cleaning the implant surface using instruments softer than titanium to remove plaque and biofilm.
   - **Antimicrobial/Antiseptic Use:** Application of topical antiseptics like chlorhexidine or hydrogen peroxide to kill bacteria.
   - **Air Powder Polishing:** Using glycine powder or other agents for air polishing to clean implant surfaces.

2. **Surgical Therapy**:
   - **Resective Therapy:** Eliminating the diseased tissue, recontouring bone, and thoroughly cleaning the implant surface to control infection.
   - **Regenerative Therapy:** Aims to regenerate lost bone and soft tissue using materials like bone grafts, membranes, and growth factors.
     - **Implant Removal:** In severe cases, the implant may need to be removed, often using a trephine bur.

3. RATIONALE FOR THE REGENERATIVE APPROACH

The majority of research on treating advanced periimplantitis employs "regenerative" procedures. By comparing the pretreatment and final follow-up radiographs, the radiographic bone gain (RBG) is calculated. Naturally, this does not indicate bone regeneration or reosteointegration to a previously denuded implant surface as a result of peri-implantitis, even though it may measure "new bone." The histology of an implant and surrounding bone is necessary for the proof of regeneration (re-osseointegration), but it might be challenging to get (particularly in the US due to IRBA and ethical concerns) on an implant where pocket reduction and bone fill were accomplished.[2]

Peri-implantitis treatment: 8 essential factors for success

S. no	Steps
1	Case selection
2	Flap access
3	Surface decontamination
4	Defect debridement
5	Defect fill
6	Coverage
7	Coronal positioning of the flap
8	Professional maintenance/monitoring

The key to successful outcomes is case selection.
A comprehensive dental and medical history is obtained. High-risk factors for achieving favorable results include smoking, a history of periodontitis, noncompliance and poor oral hygiene, systemic disease (poorly managed diabetes, cardiovascular disease, immunosuppression), a lack of keratinized tissue, and a history of one or more implant failure.[3] Before treating an implant impacted by periimplantitis, all other risk factors—aside from prior implant failures—should be addressed and managed wherever feasible. According to a previously referenced narrative analysis of effective surgical procedures, individuals who treated their periodontitis before receiving treatment for periimplantitis experienced improved treatment results.[4]

4. FLAP ACCESS

Flap access and SDC are the second and third phases of this technique. All patients received oral amoxicillin 2,000 mg (Novo Pharma) or, in the event of an amoxicillin allergy, 600 mg of Clindamycin (Ohm Laboratories) as a premedication before to flap access.

For ten more days, the patients were kept on either 500 mg of amoxicillin tid or 150 mg of clindamycin qid. According to a study on the effectiveness of preoperative antibiotics during the implantation of 2,641 implants, using preoperative antibiotics resulted in noticeably fewer failures.[5] A meta-analysis of four randomized clinical trials (RCTs) and another study of the literature revealed that the group not getting antibiotics had a statistically significantly higher number of patients reporting implant failures.[6]

As a result, the 8-step regeneration procedure was frequently used to treat advanced peri-implants with antibiotics. At least one tooth anterior and one tooth posterior to the affected implant should be extended by the flap. For complete access to the affected implant surface, the flap needs to be mirrored. Beyond what is necessary for SDC, the periosteum should be kept on the buccal and lingual bony surfaces. Periosteal releasing incisions or, if required, vertical incisions can be used to achieve this. The former permits the flaps to be positioned coronally and maintains the blood flow of the bone surrounding the implant.

5. SURFACE DECONTIMATION OF IMPLANT SURFACE (SDC)

Following mechanical debridement, SDC is carried out in tandem with comprehensive debridement of the implant surfaces and osseous defects. To remove calculus and retained cement, titanium brushes, titanium curettes, or titanium (204SD, Salvin Dental), and special graphite curettes (Gracey 13/14 curette) are used. Using the tips of the Gracey curettes, tiny decortications are produced in the intrabony portion of the defect after the osseous defect has been debrided. The seven-step mechanical and chemical methodology used by SDC comprises the following steps:

(I) An air powder abrasive spray (prophy-Jet Dentsply) with a unique contra angle tip is applied to the implant surface. Glycine is used for 60 seconds to reach all areas, and then:
(II) For one minute, use only saline spray and an irrigation device (Ace Surgical, Infinity Irrigator). The authors of a review of 27 papers that used the air powder abrasive came to the conclusion that the in-vitro experiments showed that the removal of the bacterial biofilm might reach 100% and the cleaning efficacy measured by the elimination of bacterial endotoxins ranged from 84% to 98%.[7] An review of surface detoxification and a case study on detoxification of implant surfaces warned against employing the air powder abrasive because it can leave particles on the implant surface and cause subcutaneous emphysema.[8,9] However, the authors of the eight-step regenerative procedure discovered that glycine particle attachment to the implant surface can be prevented by using a 1-minute sterile saline spray with an air powder abrasive (without any powder). Additionally, subcutaneous emphysema was prevented when the instrument's tip was positioned at a 45° angle to the implant.[10] In order to keep any powder or spray from getting behind the flap, the authors of the eight-step technique also advise holding the flaps firmly on the bone using saline-soaked gauze while holding the gauze with a mouth mirror.
(III) Using nonwoven gauze, apply 50 mg (mL) of tetracycline.
(IV) The air-powered abrasive is then used a second time with glycine for 60 seconds, and it is rinsed with sterile saline for another 60 seconds.
(V) Using non-woven gauze, apply 0.12% chlorhexidine gluconate (Peridex oral rinse 3M ESPE) to the implant surface for 30 seconds.
(VI) Sterile saline re-irrigation for 60 seconds.
(VII) Next, using nonwoven gauze, the implant surface is treated with citric acid (pH = 1) in a 50% saturated solution for 30 to 60 seconds. Rinsing vigorously for one to two minutes with sterile water comes next. Citric acid "showed the greatest efficacy in cleaning the contaminated surface," according to an assessment of the literature. Moreover, a research article which used guinea pigs showed that citric acid (50% pH-1) when applied for only 30 seconds to bone enhanced adhesion and spreading of pre osteoblasts.[11]

6. BIOLOGICS AND BONE GRAFTS

The cleaned implant surface is subsequently coated with enamel matrix derivative and/or recombinant platelet derived growth factor (rhPDGF). According to one in vitro investigation, EMD and PDGF-BD together had a stronger impact on periodontal ligament sells (PDL) cell proliferation and wound fill than each one alone.[12] Following that, a bone graft consisting of MFDBA + anorganic bovine bone (3/1 ratio) mixed with rhPDGF is used to fill the lesion in both the intrabony and suprabony regions.[13,14,15]

7. MEMBRANE BARRIERS—COLLAGEN VS. CONNECTIVE TISSUE GRAFT

A resorbable collagen barrier is created and used to protect the buccal and interproximal bone graft material in implants with a sufficient band of keratinized tissue ≥2 mm. The lingual bone graft is covered with an additional barrier piece. Surgical tacks are used to secure or sew barriers.

Extreme implant exposure has been identified as a significant risk factor for treating advanced peri-implantitis, which can lead to a loss of keratinized tissue and soft tissue morphology (74). For this reason, an SECT graft is part of the combination therapy used to treat advanced peri-implantitis. The 8-step regeneration approach involves harvesting an SECT graft from the palate and shaping it to cover the buccal and interproximal bone on implants with an insufficient band of keratinized tissue (less than 2 mm of keratinized mucosa).[16] 4-0 Vicryl sutures are used to secure the SECT in place. A comprehensive

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review examined the significance of keratinized mucosa.[17]

According to the findings, there is "more plaque accumulation, tissue inflammation, MR, and attachment loss (AL)" when there is insufficient KM surrounding endosseous dental implants. At the 3-year follow-up, a prospective longitudinal comparison study of three surgical treatments for peri-implantitis found that the SECT graft therapy group maintained the largest KM width.[18] Additionally, the graft lessens the degree of postoperative regression. The flap is positioned coronally after graft coverage. Further periosteal incisions or an extension of the vertical incisions are recommended to allow for total coverage of the membrane, graft, and implant surface without tension if the flap is unable to completely cover the graft (or if there is tension while covering the membrane and graft).

8. MAINTENANCE

Professional maintenance coupled with first-rate homecare is the final of the eight elements in the regeneration procedure. Conditions acquired after peri-implantitis surgery were shown to be stable in a 5-year follow-up trial of maintenance therapy in patients who maintained a good level of oral hygiene after the surgical treatment of peri-implantitis and were assessed every 6 months.[19] According to different 5-year research of patients with preexisting perimucositis, peri-implantitis developed in 43.9% of cases without preventative maintenance compared to 18.0% with it.[20] The authors suggested "Routine Maintenance of Dental Implants" in a commentary, along with recommendations for individuals suffering from periodontal disease. After peri-implantitis has been successfully treated, this is unquestionably required for any implant.[21]

Every three months, patients in the eight-step regeneration program were evaluated for monitoring and maintenance.[22] Every maintenance session included a thorough cleaning of the implant and a review of homecare. The authors of a literature review of 47 articles on implant maintenance came to the conclusion that professional implant maintenance (they recommend every three months), diligent patient home care, and maintenance and monitoring involving the evaluation of the patient's general and oral health "are" crucial elements that will guarantee the long-term success of implants.[23] After treating an implant with severe peri-implantitis, this is even more crucial to prevent disease recurrence and the loss of the hard and soft tissue that was accomplished with effective regeneration therapy.

As previously stated, the 8-step regenerative surgical approach is unquestionably cost-effective for retaining an implant with severe peri-implantitis. This claim was supported by a published cost-effectiveness analysis, which also emphasized the use of supporting implant therapy (SIT) to detect and prevent illness recurrence.[24] Once more, this is essential to sustaining the positive results of the eight-step regenerative strategy.

9. OUTCOME

When successful, the eight-step regenerative approach for advanced peri-implantitis avoids the need to remove the damaged implant as well as the time, risk, and cost associated with reconstructing the site and putting in a new implant. The restoration that the implant is sustaining does not need to be removed. Both the patient and the clinician typically welcome a successful outcome, even though it could take up to three treatments. As previously stated, the regimen has a 98.8% success rate when treating 170 implants, 48 of which have advanced periimplantitis.

10. INNOVATIVE MANAGEMENT STRATEGIES

The management of peri-implantitis has changed from using traditional methods to incorporating cutting-edge treatments that target immune regulation, tissue restoration, and microbial control. In order to enhance long-term results, recent advancements have concentrated on novel strategies such host modulation, targeted antimicrobial treatments, regenerative procedures, and biomaterial-based solutions. The use of adjuvant antimicrobial treatments has grown significantly in the management of periimplantitis-related biofilms. Systems that use glycine powder for air polishing have shown promise in breaking up biofilms while protecting implant surfaces. The effectiveness of air-polishing in the non-surgical treatment of peri-implantitis was confirmed by a comparison study that indicated patients treated with air-polishing had lower bleeding on probing and plaque indices than those treated with ultrasonic equipment.[25] These methods are appropriate for patients with mild to severe peri-implantitis because they guarantee little invasiveness while providing optimal biofilm management.

11. TARGETED DRUG DELIVERY SYSTEMS

The capacity of targeted medication delivery systems to localize antibacterial medicines to peri-implant areas has drawn interest. Antibiotics like minocycline or chlorhexidine are delivered to the afflicted areas in biodegradable microspheres, which enhances their antibacterial activity without causing systemic side effects. According to studies, these administration methods greatly lower inflammation and microbial burdens, enhancing the health of the tissue surrounding implants.[26]

Thanks to these developments, doctors may effectively treat infections without running the danger of long-term systemic antibiotic use.

12. IMMUNE MODULATION THERAPY

One important tactic in the treatment of peri-implantitis is immune modulation therapy. For tissue breakdown, matrix metalloproteinases (MMPs) have been inhibited by subantimicrobial-dose doxycycline. Clinical studies have shown that using doxycycline in conjunction with mechanical debridement improves soft tissue stability and lowers inflammatory markers.[27] Immune modulation offers a more comprehensive method of disease control by addressing the underlying inflammatory processes. Additionally, biomaterials are revolutionizing the way peri-implantitis is treated. The twin advantages of encouraging osseointegration and preventing bacterial colonization are provided by titanium implants coated with bioactive peptides or antimicrobial nanoparticles. For example, silver nanoparticle coatings have demonstrated potent antibacterial action and tissue compatibility, which makes them especially beneficial for high-risk patients.[28] This invention promotes tissue regeneration while lowering the risk of reinfection.

13. REGENERATIVE THERAPIES

Regenerative therapies, which aim to reverse tissue and bone loss, are at the forefront of treating periimplantitis. In order to encourage bone regeneration around implants, growth hormones such as platelet-derived growth factor (PDGF) and bone morphogenetic proteins have been used extensively. A recent study showed that considerable defect repair and increased implant stability were achieved by combining PDGF with guided bone regeneration procedures. Stem cell treatments are also being investigated; mesenchymal stem cells have the ability to regenerate the soft and hard tissues surrounding peri-implant abnormalities. It has been demonstrated that combining mechanical debridement with laser treatments can improve bacteria decrease and aid in healing. Implant surfaces can be efficiently decontaminated using lasers like Er: YAG without causing any harm to the titanium framework. They are a useful addition in the treatment of periimplantitis because of their capacity to concurrently attack biofilms and promote tissue healing, especially in complicated cases with substantial bone loss.[28]

Nanotechnology-driven solutions and bioengineered implants are examples of future management techniques. These implants incorporate sensors that can track the health of the periimplant in real time, enabling the early identification of inflammation or infection. To improve peri-implant stability over time, biofunctional coatings that release growth factors or anti-inflammatory chemicals continuously are also being explored. The potential of nutraceuticals like antioxidants and omega-3 fatty acids to promote tissue healing is also investigated by host modulation therapy. Particularly when incorporated into an all-encompassing therapy plan, these substances have demonstrated promise in lowering inflammation and promoting tissue regeneration.[29] These tactics seek to improve outcomes for patients with advanced peri-implantitis by combining localized therapy with systemic health considerations.

14. CONCLUSION

The management of peri-implantitis necessitates a comprehensive and multimodal approach that integrates advanced antibacterial, regenerative, and host-modulating strategies. Emerging innovations—such as bioengineered implant surfaces, targeted drug delivery systems, and host modulation therapies—are reshaping treatment paradigms by addressing both microbial and inflammatory pathways, thereby fostering predictable tissue regeneration. These advances not only contribute to improved implant longevity and patient well-being in line with SDG 3 (Good Health and Well-being), but also underscore the importance of continuous professional education and dissemination of evidence-based protocols consistent with SDG 4 (Quality Education). Furthermore, sustained progress in this field requires interdisciplinary collaboration and global research partnerships, reflecting the spirit of SDG 17 (Partnerships for the Goals), to ensure equitable access to cutting-edge therapies and to translate innovation into universally applicable clinical practice.

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