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Management of Peri-Implantitis Advancements and Challenges: A Narrative Review

[1]Dr. Thota Monica Shree, BDS, Goregaon Dental Centre, India

[2]Dr Miraj Desai, MDS, Vyas Dental College and Hospital, India

[3]Dr Maithreyi Venishetty, BDS, MPH, Goregaon Dental Centre, India

[4]Dr Arshiya Khan, BDS, Goregaon Dental Centre, India

Corresponding Author: Dr. Thota Monica Shree, BDS, Goregaon Dental Centre, India

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Abstract

Peri-implantitis, an inflammatory condition affecting the tissues surrounding dental implants, has become a growing concern in modern implant dentistry due to its increasing prevalence and complex etiology. The management of this condition presents significant clinical challenges, stemming from limitations in early diagnosis, variability in disease progression, and the lack of universally accepted treatment protocols. In recent years, considerable advancements have been made in both non-surgical and surgical treatment modalities. Innovations such as laser therapy, air-abrasive devices, photodynamic therapy, and the use of novel biomaterials in regenerative procedures have shown promise in improving clinical outcomes. Additionally, emerging diagnostic techniques involving molecular biomarkers and advanced imaging are contributing to earlier and more accurate detection of disease activity. Despite these developments, managing peri-implantitis remains difficult due to the multifactorial nature of the disease, patient-related risk factors, and inconsistent success rates of treatment methods. Long-term stability is often elusive, and recurrence is not uncommon. This narrative review discusses the current strategies, recent innovations, and persisting obstacles in the management of peri-implantitis, highlighting the need for continued research and the development of standardized, evidence-based clinical protocols.

Keywords: Peri-Implantitis, Photodynamic Therapy, Soft Tissues, Unpredictably

Introduction

The 2017 World Workshop consensus defined peri-implantitis as a plaque-induced pathological condition affecting the tissues surrounding dental implants, characterized by inflammation in the peri-implant mucosa and a progressive loss of supporting bone[1]. It is

considered the implant equivalent of periodontitis**,** where microbial colonization results in destructive inflammatory responses, compromising the long-term stability of the implant[2].The disease process typically starts as peri-implant mucositis**,** which is a reversible inflammation of the soft tissues surrounding an implant without bone loss. If untreated, peri-implant mucositis can progress to peri-implantitis**,** characterized by irreversible peri-implant bone resorption and a deepening of peri-implant pockets[3]**.** Unlike natural teeth, implants lack a periodontal ligament**,** which may limit their ability to resist bacterial insults and inflammatory processes.

Although patients often expect dental implants to last indefinitely, a Swedish study found that nearly half of implant recipients experienced peri-implantitis within a decade[4]. Additionally, the growing prevalence of implant surgery has led to a significant rise in peri-implantitis cases. Unlike periodontitis, peri-implantitis progresses more rapidly and unpredictably, making treatment outcomes less certain[5]. In natural teeth, collagen fibers in the connective tissue insert perpendicularly into the cementum, creating a strong mucosal seal that acts as a biological barrier. However, in dental implants, these fibers align parallel to the abutment surface, weakening the mucosal seal and reducing its protective function[6]. The macro and micro surface geometry of implant fixtures hinders complete decontamination, lowering treatment success rates.

Various treatment approaches for peri-implantitis have been adapted from periodontitis management. Mombelli and Lang proposed cumulative interceptive supportive therapy, highlighting that peri-implantitis treatment is a continuous process involving multiple therapeutic steps rather than a single procedure[7]. Several studies have examined the factors contributing to peri-implantitis, resulting in the suggestion of treatment protocols that consider these variables[8,9,10]. Sinjab et al. specifically highlighted the role of keratinized gingiva around implants, arguing that its presence is crucial for implant stability. They proposed that soft-tissue augmentation procedures, such as grafting, are necessary to effectively manage peri-implant diseases and improve long-term implant success[9]. Monje proposed a decision tree for addressing failed implants, offering surgical solutions based on peri-implant defect configuration. The ITI Treatment Guide (Volume 13) outlines a peri-implantitis protocol that combines nonsurgical and surgical treatments, followed by re-evaluation[8,10]. Treatment approaches for peri-implantitis must evolve as new scientific evidence emerges. For instance, nonsurgical therapy was previously considered ineffective due to access limitations[11]. Recent research has demonstrated improved success rates in peri-implantitis treatment when nonsurgical therapy is paired with adjunctive antibiotics, highlighting its effectiveness compared to earlier approaches[12]. A risk assessment tool has been introduced to evaluate individual peri-implantitis risk, focusing on the key factors that contribute to the disease's development[13]. The aim of this narrative review is to explore the management of peri-implantitis, highlighting current treatment options, advancements, and challenges, while proposing an updated treatment flowchart based on the latest scientific evidence.

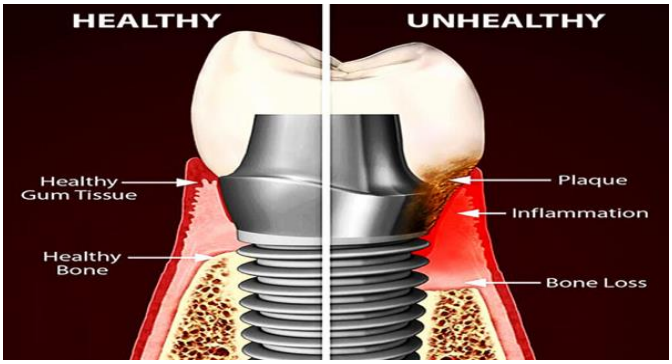

Figure 1:

Failing Implants versus Failed Implants

The phrase "ailing, failing, and failed" was first applied to dental implants by Meffert[14]. According to current diagnostic criteria for peri-implant disease, an **ailing** implant is affected by peri-implant mucositis. A **failing** implant has peri-implantitis but still holds the potential for recovery. In contrast, a **failed** implant experiences severe peri-implantitis, necessitating its removal.

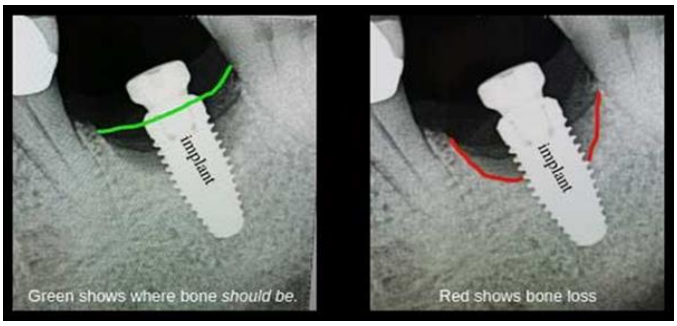

Figure 2:

Implants that exhibit mobility due to complete loss of osseointegration or fractures should be removed. Histological analysis of extracted implants with mobility has shown a total loss of bone-implant contact when the implant stability quotient (ISQ) falls to 40 or below[15]. The criteria for implant removal differ among clinicians. According to Volume 13 of the ITI Treatment Guide, the decision to remove an implant should be based on the extent of the defect and should be considered when the esthetic outcome is likely to be significantly affected[8].

Researchers recommend implant removal when bone loss exceeds 50%, as this helps eliminate inflammation and prevent further bone loss, creating a better environment for future rehabilitation[16]. Studies indicate that the failure rate of peri-implantitis treatment is 20 times higher in cases with ≥50% alveolar bone loss compared to those with ≤25% bone loss[17]. After implant removal, a second implant placement remains a viable option, with a reported survival rate of approximately 88%. However, implant failure is influenced by patient-specific factors, making it essential to manage risk factors before surgery. Additionally, ridge augmentation is often required to compensate for alveolar bone loss resulting from peri-implantitis or implant removal[18].

Nonsurgical Treatment for Peri-Implantitis

Peri-implant mucositis is the stage that precedes peri-implantitis, similar to how gingivitis progresses to periodontitis[2]. Managing peri-implant mucositis follows the principles of periodontal disease treatment and can serve as primary prevention for peri-implantitis[19]. Nonsurgical treatment is effective for peri-implant mucositis, but when the condition advances to peri-implantitis, nonsurgical methods often have limited success . Visual and instrumental access may be hindered by the prosthetic structure and bone defects, making surgical interventions necessary for adequate treatment[11,20]. To overcome these limitations, adjunctive measures to mechanical debridement have been explored, providing a less invasive approach for both clinicians and patients. Both periodontal and peri-implant diseases share a common etiology as plaque-induced inflammatory conditions, with high levels of Gram-negative and anaerobic bacteria[21]. Studies show that adjunctive antibiotic therapy improves nonsurgical treatment for peri-implantitis, based on its success in periodontal disease management[12,22].

Narts et al. observed radiologic bone gain and inflammation resolution with nonsurgical treatment using an ultrasonic scaler, glycine air abrasives, and supportive maintenance therapy every 3–6 months[22]**.** Park et al. found a significantly higher success rate in peri-implantitis treatment by combining local metronidazole and minocycline with nonsurgical treatment. The use of minocycline and the minocycline-metronidazole combination with mechanical debridement resulted in success rates of 20.5% and

31.6%, respectively, compared to 2.7% for debridement alone. However, adjunctive antibiotics carry a temporary risk of antibiotic resistance, requiring careful dosing and duration. Studies also reported successful long-term outcomes with nonsurgical treatment, using systemic metronidazole and 0.12% chlorhexidine gel. At a 4.5-year follow-up, the mean radiologic bone loss was reduced by 2.6 mm, and probing depth decreased by 4.7 mm. Poorly contoured restorations that hinder plaque control increase peri-implantitis risk[12]. Adjusting implant restorations to improve oral hygiene access enhances nonsurgical treatment outcomes and prevents inflammation rebound[23]. Removing prosthetic structures before decontamination significantly improves treatment efficacy, with a recent trial showing doubled success rates when combined with mechanical debridement and systemic metronidazole[24].

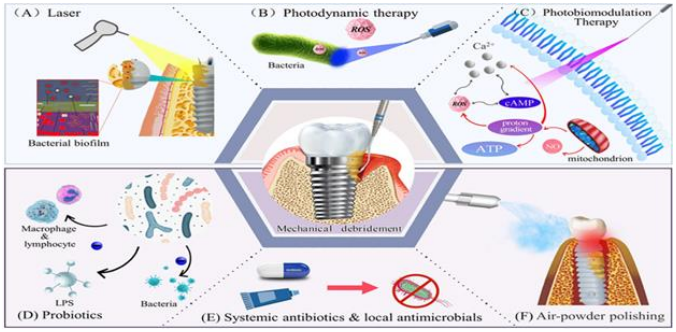

Figure 3: Non surgical treatment for peri-implantitis

Surgical Treatment for Peri-Implantitis

Surgical treatment is necessary when inflammation persists after nonsurgical therapy. There are three main surgical approaches: access surgery for surface decontamination, resective surgery to remove pathological pockets and improve hygiene access in non-regenerative defects, and reconstructive surgery to promote bone regeneration and re-osseointegration in defects with regenerative potential[25].

1. **Access surgery**

It enhances nonsurgical treatment by allowing direct surface debridement through flap elevation. Widely used in periodontitis and peri-implantitis, its long-term efficacy is established. The success of access surgery has improved with advanced surface decontamination techniques, including local minocycline delivery, titanium-coated curettes, copper-alloy ultrasonic scalers, titanium brushes, and air-powder abrasives. Though more conservative than resective surgery, it carries a risk of mucosal recession due to flap elevation[25].

2. **Resective surgery**

It is used for non-regenerative defects, such as non-contained and supracrestal defects. It includes bone recontouring, apically positioned flaps, and implantoplasty. Implantoplasty smooths exposed implant threads with a high-speed bur, reducing biofilm accumulation and bacterial regrowth without compromising biocompatibility. Thorough irrigation is essential to remove titanium particles that may cause biological complications[26].Implantoplasty also risks fracture, especially in narrow-diameter implants with internal connections[27]. Englezos et al. reported favorable outcomes over two years using an apically positioned flap, osteoplasty, and implantoplasty in severe peri-implantitis cases with significant bone loss[28].

3. **Reconstructive surgery**

It follows the same surface decontamination process as access surgery but involves filling bone defects with graft materials. The suitability of bone defects for regeneration is crucial. Monje et al. found that 58% of peri-implantitis bone defects, particularly circumferential and infraosseous defects, had regenerative potential[29]. Graft use results in greater radiographic defect fill compared to access or resective surgery[24]. Reconstructive surgery significantly reduces probing

depth and minimizes mucosal recession due to graft support[25]. However, inflammation resolution is similar to access or resective surgery. Long-term bone stability improves with growth factors like enamel matrix derivatives and platelet-derived growth factor .

In the case of defects with both intraosseous and supracrestal components, combined surgery—resective for the supracrestal part and regenerative for the intraosseous part—may be used In a recent study based on CBCT analysis, around 20% of the peri-implantitis defects had combined horizontal and intraosseous defect configurations[29]. Schwarz et al. combined implantoplasty for the supracrestal area with regeneration using bone mineral and collagen membrane, achieving over 85% BOP reduction and >2 mm clinical attachment gain over 7 years[30]. Studies showed that combined surgery with titanium brush decontamination reduced probing depth by 3–4 mm and achieved ~80% bone fill in 12 months[25].

Soft tissue quality can be improved surgically, as adequate peri-implant mucosa is essential for maintaining peri-implant health. Insufficient keratinized mucosa (<2 mm) and shallow vestibular depth hinder plaque control and cause discomfort[1,31]. Thin mucosa also compromises the mucosal seal and marginal bone stability[32]. Soft tissue augmentation with autogenous grafts or collagen substitutes enhances peri-implant conditions. An apically positioned flap with a free gingival graft is preferred for increasing keratinized mucosa, while connective tissue grafts or collagen substitutes improve mucosal thickness. A systematic review found a lower peri-implantitis prevalence in implants with soft tissue augmentation[33].

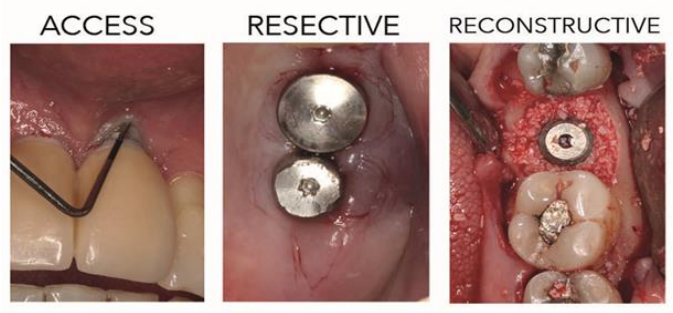

Figure 4: Surgical treatment for peri-implantitis

Challenges in Peri-Implantitis Management

Peri-implantitis remains a major challenge in implantology due to its complex causes, unpredictable progression, and lack of consensus on optimal management. Treatment is complicated by factors such as delayed diagnosis, biofilm resistance, patient-specific risks, and the limitations of existing therapies.

1. Difficulty in Early Diagnosis: A major challenge in managing peri-implantitis is the absence of a universally accepted definition and diagnostic criteria. Early-stage peri-implantitis is often asymptomatic, making detection difficult[2]. Clinically, it involves bone loss and inflammation, but differentiating between physiological remodeling and pathological loss remains problematic[3]. Furthermore, the lack of standardized probing thresholds leads to inconsistencies in diagnosing the disease[8].
2. Biofilm Resistance and Implant Surface Contamination: Peri-implantitis biofilm is highly resistant to debridement due to its complex structure and strong adhesion to rough implant surface[34]. Even with antimicrobial therapies, complete decontamination is difficult, leading to persistent bacteria and disease recurrence despite treatment efforts[24].
3. Limitations of Non-Surgical and Surgical Treatments: Non-surgical treatments like mechanical

debridement and antiseptic rinses show limited success in eliminating peri-implant biofilms, especially in deep lesions[3]. Surgical approaches, including resective and regenerative techniques, have variable outcomes influenced by defect morphology, implant surface, and patient factors[35]. However, regenerative therapies remain unpredictable due to inconsistent bone regeneration and challenges in achieving stable soft tissue sealing.

4. Patient-Related Risk Factors: Various systemic and behavioral factors increase susceptibility to peri-implantitis and complicate its management. A history of periodontitis elevates the risk due to microbial imbalance and immune response changes[36]. Smoking, diabetes, and poor oral hygiene further impair healing and immune function, worsening inflammation. Additionally, poor adherence to maintenance care increases the likelihood of reinfection and implant failure[37].
5. Implant Design and Material Considerations: Implant surface modifications, intended to improve osseointegration, can also increase peri-implantitis risk by facilitating bacterial adhesion[38]. Factors like surface roughness, thread design, and material composition affect plaque buildup and biofilm retention, influencing long-term implant health[39]. Additionally, titanium corrosion and particle release have been linked to peri-implant inflammation and bone loss[40].
6. Lack of Standardized Treatment Protocols: No universally accepted treatment protocol exists for peri-implantitis, with approaches varying from mechanical decontamination to surgical interventions[2]. The effectiveness of adjunctive therapies, including antibiotics and growth factors, remains uncertain due to inconsistent clinical data[41]. This lack of consensus complicates treatment decisions and leads to variable outcomes.
7. High Risk of Recurrence and Implant Failure: Despite aggressive treatment, peri-implantitis has a high recurrence rate, with failure rates reaching up to 40% within five years. This is due to persistent bacterial colonization, poor soft tissue sealing, and challenges in fully resolving defects. Additionally, failed implants often require complex revisions, such as bone grafting and implant replacement, increasing both the financial and biological burden[1,2,3].
8. Financial and Psychological Burden on Patients: Managing peri-implantitis is costly and time-consuming, involving multiple treatments and ongoing maintenance. Implant failure can also cause psychological distress, especially when implants serve esthetic or functional purposes. The lack of insurance coverage for complications adds to the financial strain on patients[37].

Prevention Strategies in Peri-Implantitis Management

Peri-implantitis is a major challenge in implant dentistry, leading to bone loss and implant failure. Prevention is crucial for long-term success. This review covers evidence-based strategies, including patient and implant selection, surgical protocols, prosthetic considerations, and long-term maintenance.

1. Patient Selection and Risk Factor Assessment: A key factor in preventing peri-implantitis is identifying and managing patient-related risk factors. A history of periodontitis increases the risk of peri-implant disease, as previous periodontal issues can lead to compromised implant health[2]. Smoking is another significant risk factor, as smokers tend to experience higher implant failure rates due to impaired healing and increased biofilm accumulation around the

implant[42]. Poorly controlled diabetes also elevates the risk, as it negatively impacts immune function and wound healing, making patients more susceptible to peri-implantitis[10]. Additionally, poor oral hygiene compliance plays a critical role, as patients with inadequate plaque control are more prone to peri-implant inflammation and subsequent complications[43].

2. Implant Selection and Surface Modifications: Implant design plays a crucial role in plaque accumulation and peri-implant health. While roughened surfaces promote osseointegration, they also facilitate bacterial adhesion. Antibacterial coatings, such as silver and chitosan, can reduce microbial colonization. Zirconia implants, which exhibit lower bacterial adhesion compared to titanium, may be advantageous for high-risk patients[44].
3. Optimizing Surgical Protocols: Surgical protocols are essential for maintaining peri-implant health. Minimally invasive techniques, such as flapless surgery, help reduce trauma and bacterial contamination. Proper implant positioning prevents excessive bone remodeling and soft tissue recession. Additionally, preserving keratinized tissue (≥2 mm) is linked to lower levels of peri-implant inflammation[45].
4. Prosthetic Considerations for Peri-Implant Health: Screw-retained restorations lower the risk of cement-induced peri-implantitis. A convex emergence profile makes cleaning easier and helps reduce plaque buildup. Additionally, avoiding overcontoured restorations enhances access for proper hygiene[46].
5. Peri-Operative and Post-Operative Antibiotic Use: Pre-operative antibiotics, such as 2g of amoxicillin 1 hour before surgery, may reduce the risk of early infection. However, prolonged antibiotic use should be avoided to prevent the development of antibiotic resistance[47].
6. Long-Term Maintenance and Supportive Care: Professional maintenance every 3–6 months helps prevent biofilm buildup around implants[48] Air-polishing with glycine or erythritol powder effectively removes biofilm without harming the implant surface. Routine peri-implant probing and radiographs are essential for early disease detection . Educating patients on using interdental brushes and chlorhexidine mouth rinses can significantly improve peri-implant hygiene[49].
7. Future Directions in Peri-Implantitis Prevention: Emerging treatments include photodynamic therapy (PDT) for controlling biofilm, smart implants that release antimicrobials upon detecting inflammation, and the use of salivary biomarkers for early detection of peri-implant inflammation[50,51,52].

Future Directions and Research Gaps

Peri-implantitis remains a significant challenge in implant dentistry, with current treatments showing variable success rates. Future research aims to develop innovative prevention, diagnostic, and treatment strategies to enhance long-term implant survival. This review highlights emerging technologies and existing research gaps in peri-implantitis management.

1. **Need for Standardized Treatment Protocols:** The lack of standardized treatment guidelines in peri-implantitis management results in inconsistent treatment success. Key areas requiring standardization include Establishing standardized diagnostic criteria is essential to create a consensus on peri-implantitis classification, improving comparability across studies. Additionally, defining

the most effective non-surgical decontamination methods, such as air-polishing, laser therapy, and antimicrobial agents, will enhance treatment predictability[49]. Surgical approaches also require optimization, particularly in selecting the best regenerative techniques, including flap surgery and guided bone regeneration[53]. Developing standardized clinical protocols will promote evidence-based treatment strategies, leading to improved patient outcomes.

2. **Advances in Regenerative Medicine and Personalized Therapy:** Regenerative medicine aims to restore lost bone and soft tissue around implants. Recent advancements include Biological growth factors, such as bone morphogenetic proteins (BMPs) and platelet-derived growth factors, play a crucial role in enhancing tissue healing and regeneration. The development of 3D-printed scaffolds, loaded with bioactive molecules, offers a promising approach for bone regeneration around implants. Additionally, stem cell therapy, particularly using mesenchymal stem cells, is being explored for its potential in regenerating peri-implant bone defects. Additionally, personalized treatment approaches using genetic risk assessment and microbiome analysis could help identify patients at high risk for peri-implantitis, allowing for targeted preventive and therapeutic strategies[53].
3. **Long-Term Studies on Peri-Implantitis Outcomes** Despite extensive research, long-term clinical data on peri-implantitis management remain limited. Areas needing further investigation include Assessing implant survival rates is essential for understanding the long-term prognosis of different peri-implantitis treatments[54]. Comparative studies evaluating the effectiveness of non-surgical versus surgical interventions can provide insights into the best approaches for preventing disease recurrence[9]. Additionally, systemic health factors such as diabetes, osteoporosis, and immune disorders play a crucial role in peri-implant disease progression and treatment response, highlighting the need for further research on their impact[55]. Long-term, multicenter randomized controlled trials (RCTs) are needed to validate current therapies and guide clinical decision-making.

Conclusion

Peri-implantitis remains a significant challenge in implant dentistry, requiring a comprehensive approach. While nonsurgical treatments have limited success, surgical methods incorporating surface decontamination and bone regeneration show better outcomes. However, achieving complete biofilm removal and re-osseointegration is difficult, and the absence of standardized diagnostic criteria complicates early detection. Future research should focus on standardized protocols and innovative therapies like antimicrobial coatings and regenerative techniques. Emphasizing prevention through patient education, early diagnosis, and tailored treatment strategies is crucial for reducing peri-implantitis cases and ensuring long-term implant success.

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