J Periodontal Implant Sci. 2024 Dec;54(6):377-392
https://doi.org/10.5051/jpis.2403920196
pISSN 2093-2278·eISSN 2093-2286

JPIS
Journal of Periodontal & Implant Science

Review
Implant Science

Check for updates

Current understanding of the etiology, diagnosis, treatment, and management of peri-implant diseases: a narrative review for the consensus report of the Korean Academy of Periodontology

OPEN ACCESS

Yun-Jeong Kim [1,2,†], **Young Woo Song** [3,†], **Shin-Young Park** [4], **Jae-Kook Cha** [5], **Hyo-Jung Lee** [6], **Seung-Min Yang** [7], **Jun-Beom Park** [8,*], **Ki-Tae Koo** [2,*]

[1]Department of Periodontology, Seoul National University Gwanak Dental Hospital, Seoul, Korea
[2]Department of Periodontology and Dental Research Institute, School of Dentistry, Seoul National University, Seoul, Korea
[3]Department of Periodontology, Dental Hospital, Veterans Health Service Medical Center, Seoul, Korea
[4]Department of Dental Science and Dental Research Institute, School of Dentistry, Seoul National University, Seoul, Korea
[5]Department of Periodontology, Research Institute for Periodontal Regeneration, Yonsei University College of Dentistry, Seoul, Korea
[6]Department of Periodontology, Section of Dentistry, Seoul National University Bundang Hospital, Seongnam, Korea
[7]Department of Periodontology, The Institute of Oral Health Science, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea
[8]Department of Periodontics, College of Medicine, The Catholic University of Korea, Seoul, Korea

Received: Oct 23, 2024
Revised: Dec 11, 2024
Accepted: Dec 16, 2024
Published online: Dec 30, 2024

***Correspondence:**
Jun-Beom Park
Department of Periodontics, College of Medicine, The Catholic University of Korea, 222 Banpo-daero, Seocho-gu, Seoul 06591, Korea.
Email: jbassoon@catholic.ac.kr
Tel: +82-2-2258-6290
Fax: +82-2-537-2374

Ki-Tae Koo
Department of Periodontology and Dental Research Institute, School of Dentistry, Seoul National University, 101 Daehak-ro, Jongno-gu, Seoul 03080, Korea.
Email: periokoo@snu.ac.kr
Tel: +82-2-2072-0108
Fax: +82-2-744-0051

[†]Yun-Jeong Kim and Young Woo Song equally contributed to this article.

Copyright © 2024. Korean Academy of Periodontology
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (https://creativecommons.org/licenses/by-nc/4.0/).

ORCID iDs
Yun-Jeong Kim
https://orcid.org/0000-0001-7467-4954
Young Woo Song
https://orcid.org/0000-0003-1835-5646
Shin-Young Park
https://orcid.org/0000-0002-3776-4130
Jae-Kook Cha
https://orcid.org/0000-0002-6906-7209

ABSTRACT

Over the past few decades, dental implants have been successfully utilized to replace teeth lost due to periodontal disease and other conditions. However, similar to natural teeth, dental implants are vulnerable to inflammatory peri-implant diseases, which can compromise their long-term viability. This review aims to summarize the current understanding of peri-implant diseases and discuss effective strategies for their diagnosis, treatment, and long-term management. Evidence related to peri-implant diseases was categorized and reviewed in 4 sections: 1) definition, prevalence, and classification; 2) risk indicators and etiological factors; 3) diagnostic criteria; and 4) treatment protocols for peri-implant diseases. The prevalence of peri-implant mucositis and peri-implantitis is significant, affecting 43% and 22% of implant cases, respectively. Key risk factors include poor oral hygiene, a history of periodontitis, and systemic conditions such as diabetes and smoking. The outcomes of treatment are influenced by the design of the implant prosthesis and the condition of the surrounding soft tissue. Management strategies include: 1) non-surgical treatment for implants diagnosed with peri-implant mucositis; 2) comprehensive treatment, which involves both mechanical and chemical debridement and surgical access, for implants affected by peri-implantitis; and 3) removal of failed implants, followed by the restoration of pre-existing peri-implant bone defects. Managing peri-implant diseases necessitates a comprehensive approach, encompassing risk assessment, tailored treatment planning, and stringent maintenance protocols. Regular

Generated by ⁄minlinkpress

JPIS Journal of Periodontal & Implant Science

Hyo-Jung Lee
https://orcid.org/0000-0002-0439-7389
Seung-Min Yang
https://orcid.org/0000-0002-8002-5800
Jun-Beom Park
https://orcid.org/0000-0002-8915-1555
Ki-Tae Koo
https://orcid.org/0000-0002-9809-2630

Conflict of Interest
No potential conflict of interest relevant to this article was reported.

Author Contributions
Conceptualization: Seung-Min Yang, Hyo-Jung Lee, Ki-Tae Koo; Formal analysis: Yun-Jeong Kim, Young Woo Song, Ki-Tae Koo; Investigation: Yun-Jeong Kim, Young Woo Song; Methodology: Shin-Young Park, Jae-Kook Cha; Project administration: Hyo-Jung Lee, Seung-Min Yang, Jun-Beom Park, Ki-Tae Koo; Writing - original draft: Yun-Jeong Kim, Young Woo Song; Writing - review & editing: Shin-Young Park, Jun-Beom Park, Ki-Tae Koo.

follow-ups and patient education are critical for preventing disease recurrence and ensure the long-term success of implant therapy.

Keywords: Clinical protocols; Diagnosis; Peri-implantitis; Risk factors

INTRODUCTION

For decades, dental implants have been effectively utilized to replace missing teeth. The first long-term observational study on the survival of implants placed in edentulous areas to support fixed dental prostheses was published in the early 1980s [1]. Since then, the use of implants has expanded to include both partially edentulous areas and single missing teeth. With increasing life expectancy and an aging population, we are now in an 'era of widespread implant therapy.' In Korea, where over 20% of the population is aged 65 and older, more than 8.7% of older adults benefit from dental implant treatments provided through the National Health Insurance [2]. The increasing prevalence of these implants, particularly among older adults, presents a dual challenge: managing the higher costs of long-term care due to peri-implantitis and addressing the significant impact on patient quality of life [3]. Modern implants offer high durability and aesthetic appeal but also bring an economic burden due to their maintenance. This highlights the importance of developing comprehensive treatment strategies that ensure the long-term viability of implants while optimizing patient outcomes through preventive measures and effective complication management. These strategies are essential for maintaining healthcare efficiency and improving the daily lives of patients affected by peri-implant diseases.

Dental implants require successful osseointegration at the bone-implant interface and soft-tissue integration in the transmucosal region, all within an oral microenvironment filled with pathogenic bacteria. This presents a significant challenge for achieving initial stability and ensuring the long-term viability of the implants, especially in patients with complicating factors such as advanced age, smoking habits, or diabetes [4]. In general, peri-implantitis progresses more rapidly and unpredictably compared to periodontitis, and it also yields less predictable treatment outcomes. This issue stems from the parallel alignment of collagen fibers around the implants, which impairs the mucosal seal that serves as a biological barrier. Additionally, the complex surface characteristics of the implant fixture, including thread structures and rough surfaces, complicate effective decontamination and diminish the likelihood of treatment success [5].

This paper provides an overview of the current understanding of peri-implant disease, including its prevalence and the risk factors that contribute to its progression. Additionally, it outlines the diagnostic criteria and treatment protocols for peri-implant disease, drawing on key consensus reports published to date.

SUMMARY STATEMENTS IN THE AREAS OF PERI-IMPLANT DISEASE PREVALENCE, CLASSIFICATION, AND DEFINITION

How can implant complications be classified?

Early implant complications typically involve the failure of osseointegration between the implant surface and the alveolar bone. This failure can be attributed to factors such as

https://doi.org/10.5051/jpis.2403920196

inappropriate surgical techniques, various types of surgical trauma, poor bone quality at the surgical site, and infection. Numerous studies have highlighted the significant impact of the surgeon's expertise on the rate of early implant failures [6-9]. Complications following prosthesis placement can be categorized into biological complications, which cause inflammation in the tissues surrounding the implant, and mechanical (prosthetic) complications, based on their causes. Once it is established that the implant has been correctly placed and all potential factors for early failure have been addressed, attention turns to biological complications, particularly peri-implant diseases. The questions below address scenarios in which the clinician suspects that biofilms on the implant surfaces are the primary etiological factors contributing to the development of peri-implant mucositis and peri-implantitis.

What is the definition of peri-implantitis?

Peri-implantitis is a destructive inflammatory process affecting functionally osseointegrated implants, characterized by bleeding in the soft tissues around the implant, increased periodontal pocket depth, and loss of alveolar bone [10]. According to the consensus report from the 2017 World Workshop for the Classification of Periodontal and Peri-Implant Diseases and Conditions, peri-implantitis is defined as "a pathological condition of dental plaque origin occurring in the tissues surrounding dental implants, characterized by inflammation of the mucosa surrounding the implant and subsequent progressive loss of supporting bone" [11].

What is the current prevalence of peri-implantitis?

Recent reports indicate that biological complications occurred in 52% of cases, while mechanical (prosthetic) complications were observed in 32% during the follow-up period [12]. Meta-analyses have estimated the weighted mean prevalence rates of peri-implant mucositis and peri-implantitis to be 43% (95% confidence interval [CI], 32%–54%) and 22% (95% CI, 14%–30%), respectively [13]. Renvert et al. [14] reported prevalences of peri-implantitis and peri-implant mucositis at 22.1% and 54.7%, respectively, in subjects 21–26 years post-implant placement, with an average follow-up duration of 23.3 years. A study conducted in Korea reported an overall implant survival rate of 95.87%, with peri-implant mucositis occurring in 39.7% of cases and peri-implantitis in 16.7% [15].

Does a prior history of periodontitis influence the incidence of peri-implantitis?

Research has shown that patients who have undergone periodontal treatment are at a statistically significantly higher risk of developing peri-implantitis and experiencing implant loss compared to those without a history of periodontal disease [16]. Meta-analyses of patient data indicate that individuals with periodontitis face a 2.29 times greater risk of peri-implantitis than those who are periodontally healthy [17].

In a study utilizing the recently revised classification system, no statistically significant correlation was observed between the stage or grade of periodontitis and the prevalence of peri-implantitis. However, it was reported that grade C periodontitis is associated with an increased risk of implant failure and more extensive marginal bone loss [18].

What other factors influence the prevalence of peri-implantitis?

Systemic conditions such as osteoporosis and diabetes, along with a patient's history of periodontitis, significantly increase the risk of peri-implantitis by impairing immune function and healing processes. Factors related to the implant also play a critical role in the

https://doi.org/10.5051/jpis.2403920196

prevalence of peri-implantitis. Differences in prosthesis type, specifically between cemented and screw-retained, as well as variations in implant diameter and mucosal height, can lead to increased plaque accumulation and inflammation of peri-implant tissues [19].

Moreover, surgical precision is crucial, as improper placement of an implant is associated with a higher risk of peri-implantitis. A study [8] has highlighted that surgical errors are more commonly linked to peri-implantitis (40.8%) than to prosthetic (30.4%) or purely plaque-induced (28.8%) factors.

Differences in diagnostic criteria, implant systems, and clinician expertise contribute further to discrepancies in reported prevalence rates. Standardizing these factors is essential for a comprehensive understanding and effective management of peri-implantitis.

SUMMARY STATEMENTS IN THE AREAS OF SYSTEMIC/ LOCAL RISK INDICATORS AND ETIOLOGICAL FACTORS OF BIOLOGIC COMPLICATIONS

What are the major risk indicators for peri-implantitis?

Peri-implant diseases are caused by bacterial biofilms and are associated with specific risk indicators/factors [20]. The most significant risk indicators include poor oral hygiene, irregular maintenance, and a history of chronic periodontitis, including cases that remain untreated [11,21].

Research on peri-implantitis treatment indicates that anti-infective strategies are effective in reducing soft tissue inflammation and preventing the progression of peri-implant disease [11].

What are the systemic and behavioral risk indicators of peri-implantitis?

At the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions, it was noted that smoking and diabetes are potential risk indicators for peri-implant diseases [11]. Poorly controlled or uncontrolled type 2 diabetes increases the risk of complications by 2.75 times [22]. Chronic hyperglycemia disrupts implant-related bone regeneration by impairing angiogenesis [23]. Diabetes reduces bone formation markers such as osteocalcin, alkaline phosphatase, and procollagen type 1 N-terminal propeptide, and it promotes bone resorption by accumulating Advanced Glycation End Products, which trigger systemic inflammation [24]. Supportive maintenance programs have significantly reduced peri-implant complications in individuals with type 2 diabetes, bringing their outcomes closer to those of non-diabetic individuals over time [25].

Most of the literature presents scientific evidence supporting smoking as a risk factor for developing peri-implant disease [26]. Additionally, the risk of peri-implantitis increases with long-term use of non-steroidal anti-inflammatory drugs (3.2×), bisphosphonates (2.69×), and alcohol consumption exceeding 5 units per day (2.3×) [27]. Head and neck irradiation therapy decreases implant survival rates by 2.63 times, especially when implants are placed within 12 months of receiving radiation, regardless of the radiation dose [27]. According to the consensus report, implant treatment is contraindicated in cases of high-dose antiresorptive therapy due to complications; however, the risk of osteonecrosis remains low with low-dose drugs, as typically used in treating general osteoporosis [28].

https://doi.org/10.5051/jpis.2403920196

Before considering implant surgery for these patients, it is necessary to conduct a thorough individual risk assessment. Additionally, patients with comorbidities must be closely monitored in collaboration with the supervising physician and undergo regular follow-up [29].

What additional risk factors for peri-implantitis have been identified?

There is limited evidence suggesting a link between peri-implantitis and factors such as submucosal excess cement residue [30] and implant positioning that impedes oral hygiene and maintenance. The roles of other potential risk indicators, including peri-implant keratinized mucosa, occlusal overload, titanium particles, bone compression necrosis, overheating, and micromotion, have yet to be fully determined [11]. Sarmiento et al. [31] revealed that most bone loss around implants is related to the accumulation of biofilm, followed by iatrogenic factors, exogenous stimuli, absence of keratinized gingiva, and exogenous pathology. This suggests that while bacterial plaque is the primary cause of inflammation, various issues during implant surgery or prosthetic procedures may also contribute to plaque accumulation, complicating the attribution of this issue solely to the patient's poor oral hygiene.

What is the impact of design elements of the implant supracrestal complex (ISC) on the risk of peri-implant mucositis and peri-implantitis?

The ISC is defined as the anatomical and functional region that includes the various components of the implant–abutment–prosthesis junction situated within the mucosal area [20]. Evidence suggests that modifying the prosthesis can enhance the effectiveness of peri-implant mucositis treatment when the original design of the prosthesis hinders access to oral hygiene [32].

The concept of platform switching, along with advancements in implant design, has led to the increasing belief that achieving zero bone loss is possible. The positioning of the prosthesis margin's microgap further from the alveolar crest level creates more favorable conditions for preventing inflammation [33].

Recent research results indicate that the prevalence of peri-implantitis is high when the emergence angle exceeds 30° and is combined with a convex emergence profile of the abutment/prosthesis [20], and when the implant prosthesis is splinted to both the mesial and distal adjacent implants [34].

What are the risks of positioning the crown margin below the mucosa level?

To optimize aesthetics, prostheses are often positioned below the mucosal margin. However, particularly in the posterior region, maintaining hygiene becomes challenging when the abutment-prosthesis interface is situated beneath the mucosal level. Moreover, there is a significantly higher risk of residual cement at subgingival abutment margins compared to supragingival and equigingival margins [35]. In the case of the cement-retained type, these cement residues can act as foreign bodies, causing inflammation and bone loss [36]. Limited evidence suggests that the risk of peri-implantitis increases when the distance between the crown restoration margin and the bone crest is less than 1.5 mm. Therefore, selecting the appropriate abutment is crucial to avoid placing submucosal crown margins too close to the alveolar bone crest, whether the prosthesis is screwed or cemented [36].

Does the soft-tissue phenotype surrounding the implant affect peri-implant diseases?

Recent recommendations have highlighted the importance of assessing changes in peri-implant soft tissue parameters, in addition to focusing on disease resolution following

https://doi.org/10.5051/jpis.2403920196

surgical treatment of peri-implantitis [20]. Research has emphasized that when gingival thickness is less than 3 mm, there is a risk of bone resorption to maintain a minimal soft tissue attachment around the implant [37]. Therefore, it is necessary to consider prosthetic interventions such as soft tissue grafting, using prostheses with smoothly polished surfaces, selecting abutments that are highly biocompatible with the gingiva, and employing removable screw-type prostheses.

The stability of the marginal mucosa relies not only on the characteristics of the peri-implant soft tissue but also on the condition of the underlying alveolar bone. If there is a bone dehiscence, it can cause mucosal recession, which subsequently heightens the risk of peri-implantitis, particularly when a rough area of the implant surface becomes exposed [36].

What are common problems associated with lack of keratinized mucosa (width)?

According to the current consensus, having enough high-quality keratinized gingiva is beneficial for controlling dental plaque. When keratinized gingiva is insufficient, soft tissue grafting is recommended to increase stability [38]. A meta-analysis has shown that inadequate keratinized gingiva around implants is linked to increased accumulation of dental plaque, as well as to gingival inflammation, recession, and attachment loss [39]. Numerous reviews have observed improvements in both the plaque index and the gingivitis index at sites where soft tissue grafting was performed to increase keratinized gingiva [40]. Although evidence regarding the long-term success rates of implants and their impact on complications remains limited, it is clinically clear that adequate keratinized gingiva around implants supports patient oral hygiene, improves aesthetic outcomes, and aids in accurate impression taking. Therefore, it is a critical factor to consider during the surgical planning phase.

DIAGNOSIS AND CLINICAL CHARACTERISTICS OF PERI-IMPLANTITIS

Diagnosis of peri-implant diseases

Peri-implant diseases and related conditions encompass both plaque-induced and non-plaque-associated issues, including implant mucosal recession, mucosal hyperplasia, trauma-induced lesions, and other non-specific clinical conditions. The diagnosis of these peri-implant diseases, whether related to plaque or not, primarily depends on the detection of a plaque-induced active infection. This is indicated by symptoms such as bleeding on probing, exudate or suppuration, radiographic bone loss, and increased probing pocket depth [41].

How to define and diagnose peri-implant health, peri-implant mucositis and peri-implantitis

The following criteria are considered for defining the condition of peri-implant tissue [11,41].

Peri-implant health

- Absence of bleeding and suppuration on gentle probing;
- No increase in probing depth compared to previous examinations;
- No bone loss beyond the changes in marginal bone levels associated with initial bone remodeling.

https://doi.org/10.5051/jpis.2403920196

Peri-implant mucositis

- Presence of bleeding and/or suppuration upon gentle probing, with or without an increase in probing depth relative to previous evaluations;
- No bone loss beyond marginal bone level changes resulting from initial bone remodeling.

Peri-implantitis

- Presence of bleeding and/or suppuration on gentle probing;
- Increased probing depth compared to previous measurements;
- Bone loss extending beyond the marginal bone level changes due to initial bone remodeling.

In cases where prior examination data are unavailable, the diagnosis of peri-implantitis could be made based on the following combination of factors

- Bleeding and/or suppuration on gentle probing;
- Probing depths of ≥6 mm;
- Bone levels ≥3 mm apical of the most coronal portion of the intra-osseous part of the implant.

What are the tools for the diagnosis of peri-implant mucositis or peri-implantitis?

Early detection of inflammation is crucial for preventing peri-implant diseases. Marginal bone resorption around functioning implants is assessed using long-cone parallel radiographic projection techniques. Bleeding on probing serves as a key clinical indicator of soft tissue inflammation, helping to distinguish between peri-implant health, mucositis, and peri-implantitis. A periodontal probe is vital for monitoring the health of peri-implant tissues, with measurements influenced by factors such as inflammation, probing force, implant position, prosthetic contour, and the type of probe used. Plastic probes, which are more flexible, may record deeper depths compared to stainless steel probes, making it essential to maintain consistency in the type of probe used across examinations [41]. Furthermore, the established relationship between probing force and the frequency of bleeding on probing in healthy teeth indicates that excessive probing force can sometimes cause bleeding in surrounding tissues due to tissue trauma [29].

TREATMENT PROTOCOL FOR PERI-IMPLANT DISEASES

Since bacterial plaque is recognized as the primary etiological factor in peri-implant disease [42,43], current treatment approaches commonly align with those established for periodontitis [5].

Non-surgical treatment

Peri-implant mucositis is regarded as a precursor to peri-implantitis, similar to how gingivitis precedes periodontitis [21]. Non-surgical treatments are effective in managing peri-implant mucositis and serve as a preventive measure against peri-implantitis [44]. However, when the condition advances to peri-implantitis, non-surgical treatments typically become inadequate due to restricted visual and instrumental access, thus requiring surgical intervention [45,46].

To address this limitation, various solutions have been proposed. Removing the prosthesis has been shown to increase treatment efficacy by facilitating better access during non-surgical procedures [47]. Additionally, the combined use of systemic and local antibiotics

https://doi.org/10.5051/jpis.2403920196

with non-surgical debridement has been explored. Studies indicate that integrating non-surgical treatment with antibiotics, including metronidazole and minocycline, improves outcomes for peri-implantitis, though careful consideration of antibiotic resistance is necessary [48-52].

The design of implant restorations plays a critical role in the success of treatment. Over-contoured restorations that impede plaque control can increase the risk of peri-implantitis [34,53]. Conversely, adjusting the restoration to improve oral hygiene accessibility can significantly enhance the outcomes of non-surgical treatments [32]. It is crucial to ensure adequate embrasure space for self-cleansing, which involves maintaining a minimum horizontal distance of at least 1.5 mm from the implant to the adjacent teeth or at least 3 mm to an adjacent implant [54,55]. Additionally, the abutment should be designed with a concave shape to optimize the health and volume of the peri-abutment mucosa and to prevent unexpected bone resorption [34,53,56,57]. This is particularly critical for the middle implant in a multi-unit prosthesis that is splinted to both the mesial and distal adjacent implants [34]. It is also important to monitor for the loss of proximal contact, which can lead to food impaction, previously observed between the implant and the mesial tooth [58].

Surgical treatment

It is well known that a surgical approach was once considered inevitable for treating peri-implantitis lesions. Currently, there are several treatment modalities that clinicians can choose from based on the clinical situation [5,59]: access surgery, resective surgery, and regenerative surgery.

Access surgery

Access surgery, the most fundamental of surgical approaches, can be described as open flap debridement. This method is widely recognized as effective for the meticulous decontamination of the affected implant surface [60]. The main objective of this procedure is to thoroughly decontaminate the surface, which is essential for minimizing bacterial recolonization and enhancing re-osseointegration [61]. Traditional mechanical debridement tools, such as metal curettes and ultrasonic scalers, can damage the titanium surface of implants. Therefore, alternatives like titanium curettes, ultrasonic scalers with plastic tips, air powder abrasives, or rotating titanium brushes have been suggested and proven effective [62,63].

Despite the challenges posed by the surface topography of implant fixtures, which make it difficult to fully decontaminate affected areas, especially when access is restricted by prostheses or deep intrabony defects [5], chemical agents have been employed as adjuncts to enhance surface decontamination [64]. Previous research has shown that these agents, including citric acid, hydrogen peroxide, ethylene-diamine-tetraacetic acid, and chlorhexidine, are effective in reducing or eliminating bacteria and endotoxins on the implant surface, thereby improving treatment outcomes [65-67]. However, there is still no consensus on which chemical or pharmacological agent is the most effective [68].

Resective approach

When peri-implantitis results in a defect with a less contained or supracrestal configuration where regeneration is not indicated, resective surgery may be selected to facilitate better oral hygiene control during post-operative follow-up [5]. This approach involves a sequential procedure that includes: 1) contouring the bone to positively alter the peri-implant bone profile; 2) performing implantoplasty, which entails removing the supracrestally exposed

https://doi.org/10.5051/jpis.2403920196

implant threads and polishing the surface; and 3) apically repositioning the mucoperiosteal flap to reduce mucosal pocket depth [69]. Consequently, this may reduce the likelihood of biofilm accumulation and bacterial regrowth after the surgery, leading to a favorable long-term outcome [70].

In the meanwhile, there are some concerns regarding implantoplasty. First, while it increases surface smoothness, it may lead to biological complications due to titanium particles that are not completely removed [71]. Second, there is an increased risk of fixture fracture or tearing, especially in narrow-diameter implants with internal connections. This risk arises because thread removal results in a thinner wall surrounding the screw [72].

Regenerative approach

In regenerative surgery, peri-implant defects are addressed by filling them with bone graft materials after the affected fixture surface has been decontaminated. The predictability of treatment outcomes is highly dependent on the configuration of the defect. Research has shown that circumferential, 2- or 3-wall intrabony defects exhibit higher regenerative potential [73]. While grafting bone substitutes into the defect results in radiographic defect fill, reduced probing pocket depth, and minimized postoperative mucosal recession, it does not significantly differ from resective or access flap surgery in terms of resolving inflammation [74]. Additionally, some studies have suggested that outcomes may be improved when bone grafting is combined with growth factors such as enamel matrix derivative or platelet-derived growth factor [73].

In cases where defects include both suprabony and intrabony compartments, a combination of resective and regenerative procedures may be suitable [74]. This approach entails performing resective surgery on the suprabony component and regenerative surgery on the intrabony component, effectively accomplishing both inflammation relief and bone regeneration simultaneously.

Adjunctive soft tissue grafting

Regardless of the type of surgical treatment, it is advisable to include soft tissue grafting (using either autogenous tissue or a collagen substitute) as needed. This is because peri-implant soft tissue of adequate quality and thickness is considered crucial for maintaining peri-implant health and reducing the risk of peri-implantitis recurrence [43]. When there is less than 2 mm of keratinized mucosa and a shallow vestibule, patients are likely to experience discomfort and difficulties with self-plaque removal [75]. Moreover, thin mucosa may limit the mucosal seal, potentially leading to adverse effects on marginal bone stability [76].

Fixture removal

Once an implant is deemed to have failed, the clinician's only option may be to remove the compromised fixture [77]. Although there is controversy surrounding the definitive criteria for removing an implant diagnosed with peri-implantitis, it is generally recommended to remove the implant if 1) the implant is mobile due to complete loss of osseointegration [78], 2) there is a fracture or tearing of the fixture [79,80], or 3) peri-implant bone loss exceeds half of the total implant length [81]. While the extent of vertical bone loss may be debatable, the failure rate of peri-implantitis treatment is approximately 20 times higher when less than 50% of the bone remains in contact with the implant [82].

https://doi.org/10.5051/jpis.2403920196

Maintenance care after the peri-implantitis treatment

Similar to the management of periodontitis, regular maintenance is crucial for peri-implantitis. To optimize this maintenance, it is essential to evaluate the risk of peri-implantitis. The Implant Disease Risk Assessment (IDRA) tool has been developed to assess patient-level risks by examining eight key risk factors, including history of periodontitis, prevalence of probing depths, and factors related to the implant prosthesis [83]. This tool categorizes patients into low, moderate, or high-risk groups, which aids in designing personalized maintenance programs and enhances communication and motivation with patients. Based on individual risk levels, regular maintenance visits are recommended every 3–6 months, as intervals longer than 6 months have been shown to reduce the effectiveness of maintenance.

Periodic supportive therapy, including the removal of supra- and submucosal biofilm at least once every 6 months, effectively maintains the clinical success of treatments. Research has shown that maintenance, including plaque control and adjunctive local antibiotic applications every 3–6 months, reduces the prevalence of peri-implantitis [84,85]. However, the optimal frequency for maintenance recalls to ensure peri-implant tissue health remains unclear. A recent systematic review and meta-analysis revealed that a 6-month interval yielded better outcomes compared to a 3-month interval [84], a finding that warrants further investigation to determine the underlying reasons. It is widely recognized that patient compliance plays a crucial role in the health of peri-implant tissues. Studies have indicated that non-compliance or reduced compliance significantly increases the prevalence of peri-implant diseases [86]. A previous cross-sectional study reported that patients with erratic compliance (fewer than 2 visits per year) had a higher likelihood of experiencing peri-implant disease compared to those with regular compliance (2 or more visits per year) [85]. Furthermore, a recent prospective study showed that individuals adhering to a regular maintenance schedule with intervals not exceeding 9 months maintained better peri-implant tissue health than those with irregular schedules and intervals of up to 18 months [87]. This underscores clinicians' critical role in ensuring patients adhere to maintenance protocols. Achieving this may require thorough motivational interventions and reinforcement [88]. Additionally, for patients covered by public insurance or assistance, such as Korean citizens, leveraging national policies could also be an effective strategy to increase compliance.

CLINICAL RECOMMENDATIONS

Based on the current understanding of peri-implant diseases, the following clinical recommendations are proposed (**Figure 1**).

In cases of peri-implant mucositis

Similar to gingivitis, peri-implant mucositis can be successfully managed with non-surgical treatment [44]. Given that dental plaque is the primary etiologic factor of peri-implantitis [89], it is important for both clinicians and patients to maintain rigorous oral hygiene.

Beforehand, it is crucial for clinicians to establish an appropriate environment around the implant to optimize peri-implant tissue health. First, a sufficient amount and good quality of both soft and hard tissue should surround the fixture, particularly at the crestal level [43]. Second, the depth at which the implant is placed should ensure an adequate supracrestal mucosal thickness, which serves as a biological barrier [90,91]. Third, the design of the prosthesis is critical; it is advisable to avoid over-contoured prostheses [34,53]. If necessary, the prosthesis compartments should

https://doi.org/10.5051/jpis.2403920196

JPIS
Journal of Periodontal & Implant Science

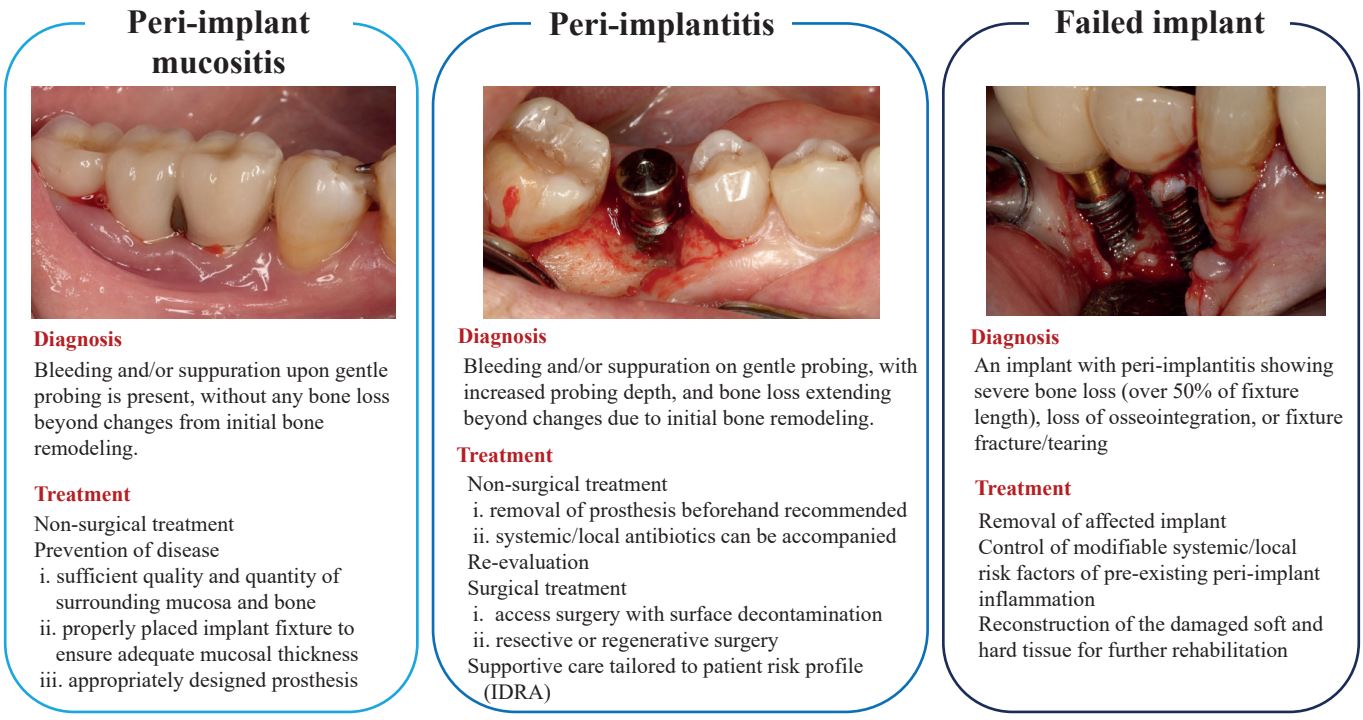

Figure 1. Clinical recommendations for peri-implant diseases.
IDRA: implant disease risk assessment.

be adjusted to facilitate self-cleansing at the embrasure, especially when the middle implant is splinted with both mesial and distal adjacent fixtures [34]. Finally, the clinician must meticulously remove any excess luting cement after placing the cement-retained prosthesis [92].

In cases of peri-implantitis

For implants diagnosed with peri-implantitis that are not severe enough to require removal, comprehensive treatment typically starts with non-surgical methods, such as mechanical and chemical debridement [44]. In most cases, removing the prosthesis prior to treatment is beneficial to improve accessibility. The use of systemic or local antibiotics is strongly recommended. A re-evaluation is usually conducted 3 months after the non-surgical treatment to determine subsequent steps [5].

If non-surgical treatment fails to sufficiently improve peri-implant conditions, surgical intervention is recommended [5,59]. CBCT analysis is crucial for confirming defect configurations, which assists in determining whether to opt for resective, access, reconstructive surgery, or a combination of these approaches [74]. After successful treatment, patients should be enrolled in a maintenance program. The frequency of recall visits should be determined by risk assessments using the IDRA tool [83]. Each visit should include professional plaque control and reinforcement of oral hygiene practices, along with continuous re-evaluation to ensure the stability of peri-implant conditions. If conditions deteriorate, the treatment cycle must be restarted, underscoring the chronic nature of peri-implantitis and the necessity for ongoing management [21].

https://doi.org/10.5051/jpis.2403920196

For failed implants

Clinicians should consider removing a failed implant characterized by loss of osseointegration or fixture fracture/tearing [77]. Additionally, it is advisable to remove fixtures that exhibit severe peri-implant bone loss exceeding 50% of the fixture length, due to the poor predictability of treatment outcomes [81]. This approach may be particularly favored in South Korea, where patients are generally more willing to opt for re-implantation due to its cost-effectiveness [93].

Removal of the affected implant completely alleviates the inflammation, but it also presents clinicians with the challenge of reconstructing the soft and hard tissues damaged by pre-existing peri-implantitis to restore function and aesthetics. Prior to this reconstruction, it is essential to thoroughly address all factors that contributed to the previous implant failure, ensuring that the newly installed implant does not encounter the same issues [94].

CONCLUSIONS

It is critical for clinicians to manage peri-implant diseases comprehensively, which includes conducting an in-depth risk assessment, developing individualized treatment plans, and establishing thorough maintenance protocols. Additionally, regular follow-ups and patient education are crucial to prevent disease recurrence and ensure the long-term health of peri-implant tissues.

REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387-416. PUBMED | CROSSREF
2. Analysis of dental outpatient treatment status [Internet]. Wonju: Health Insurance Review & Assessment Service; 2023 [cited 2024 Jul 20]. Available from: https://opendata.hira.or.kr/home.do.
3. Saleh MHA, Dias DR, Kumar P. The economic and societal impact of periodontal and peri-implant diseases. Periodontol 2000. Forthcoming 2024. PUBMED | CROSSREF
4. Gulati K, Chopra D, Kocak-Oztug NA, Verron E. Fit and forget: the future of dental implant therapy via nanotechnology. Adv Drug Deliv Rev 2023;199:114900. PUBMED | CROSSREF
5. Hong I, Koo KT, Oh SY, Park HW, Sanz-Martín I, Cha JK. Comprehensive treatment protocol for peri-implantitis: an up-to date narrative review of the literature. J Periodontal Implant Sci 2024;54:295-308. PUBMED | CROSSREF
6. Jemt T. A retro-prospective effectiveness study on 3448 implant operations at one referral clinic: a multifactorial analysis. Part I: clinical factors associated to early implant failures. Clin Implant Dent Relat Res 2017;19:980-8. PUBMED | CROSSREF
7. Greenstein G, Cavallaro J, Romanos G, Tarnow D. Clinical recommendations for avoiding and managing surgical complications associated with implant dentistry: a review. J Periodontol 2008;79:1317-29. PUBMED | CROSSREF
8. Canullo L, Tallarico M, Radovanovic S, Delibasic B, Covani U, Rakic M. Distinguishing predictive profiles for patient-based risk assessment and diagnostics of plaque induced, surgically and prosthetically triggered peri-implantitis. Clin Oral Implants Res 2016;27:1243-50. PUBMED | CROSSREF
9. Monje A, Galindo-Moreno P, Tözüm TF, Suárez-López del Amo F, Wang HL. Into the paradigm of local factors as contributors for peri-implant disease: short communication. Int J Oral Maxillofac Implants 2016;31:288-92. PUBMED | CROSSREF
10. Kordbacheh Changi K, Finkelstein J, Papapanou PN. Peri-implantitis prevalence, incidence rate, and risk factors: a study of electronic health records at a U.S. dental school. Clin Oral Implants Res 2019;30:306-14. PUBMED | CROSSREF

11. Berglundh T, Armitage G, Araujo MG, Avila-Ortiz G, Blanco J, Camargo PM, et al. Peri-implant diseases and conditions: consensus report of workgroup 4 of the 2017 World Workshop on the classification of periodontal and peri-implant diseases and conditions. J Periodontol 2018;89 Suppl 1:S313-8. PUBMED | CROSSREF
12. Adler L, Buhlin K, Jansson L. Survival and complications: a 9- to 15-year retrospective follow-up of dental implant therapy. J Oral Rehabil 2020;47:67-77. PUBMED | CROSSREF
13. Derks J, Tomasi C. Peri-implant health and disease. A systematic review of current epidemiology. J Clin Periodontol 2015;42 Suppl 16:S158-71. PUBMED | CROSSREF
14. Renvert S, Lindahl C, Persson GR. Occurrence of cases with peri-implant mucositis or peri-implantitis in a 21–26 years follow-up study. J Clin Periodontol 2018;45:233-40. PUBMED | CROSSREF
15. Ahn DH, Kim HJ, Joo JY, Lee JY. Prevalence and risk factors of peri-implant mucositis and peri-implantitis after at least 7 years of loading. J Periodontal Implant Sci 2019;49:397-405. PUBMED | CROSSREF
16. Sgolastra F, Petrucci A, Severino M, Gatto R, Monaco A. Periodontitis, implant loss and peri-implantitis. A meta-analysis. Clin Oral Implants Res 2015;26:e8-16. PUBMED | CROSSREF
17. Ferreira SD, Martins CC, Amaral SA, Vieira TR, Albuquerque BN, Cota LOM, et al. Periodontitis as a risk factor for peri-implantitis: systematic review and meta-analysis of observational studies. J Dent 2018;79:1-10. PUBMED | CROSSREF
18. Ravidà A, Rodriguez MV, Saleh MHA, Galli M, Qazi M, Troiano G, et al. The correlation between history of periodontitis according to staging and grading and the prevalence/severity of peri-implantitis in patients enrolled in maintenance therapy. J Periodontol 2021;92:1522-35. PUBMED | CROSSREF
19. Apaza-Bedoya K, Galarraga-Vinueza ME, Correa BB, Schwarz F, Bianchini MA, Magalhães Benfatti CA. Prevalence, risk indicators, and clinical characteristics of peri-implant mucositis and peri-implantitis for an internal conical connection implant system: a multicenter cross-sectional study. J Periodontol 2024;95:582-93. PUBMED | CROSSREF
20. Schwarz F, Alcoforado G, Guerrero A, Jönsson D, Klinge B, Lang N, et al. Peri-implantitis: summary and consensus statements of group 3. The 6th EAO consensus conference 2021. Clin Oral Implants Res 2021;32 Suppl 21:245-53. PUBMED | CROSSREF
21. Schwarz F, Derks J, Monje A, Wang HL. Peri-implantitis. J Periodontol 2018;89 Suppl 1:S267-90. PUBMED | CROSSREF
22. Kumar PS. Systemic risk factors for the development of periimplant diseases. Implant Dent 2019;28:115-9. PUBMED | CROSSREF
23. Hu XF, Wang L, Xiang G, Lei W, Feng YF. Angiogenesis impairment by the NADPH oxidase-triggered oxidative stress at the bone-implant interface: critical mechanisms and therapeutic targets for implant failure under hyperglycemic conditions in diabetes. Acta Biomater 2018;73:470-87. PUBMED | CROSSREF
24. de Oliveira PGFP, Bonfante EA, Bergamo ETP, de Souza SLS, Riella L, Torroni A, et al. Obesity/metabolic syndrome and diabetes mellitus on peri-implantitis. Trends Endocrinol Metab 2020;31:596-610. PUBMED | CROSSREF
25. Al Amri MD, Kellesarian SV, Al-Kheraif AA, Malmstrom H, Javed F, Romanos GE. Effect of oral hygiene maintenance on HbA1c levels and peri-implant parameters around immediately-loaded dental implants placed in type-2 diabetic patients: 2 years follow-up. Clin Oral Implants Res 2016;27:1439-43. PUBMED | CROSSREF
26. Casado PL, Aguiar T, Fernandes Pinheiro MP, Machado A, da Rosa Pinheiro A. Smoking as a risk factor for the development of periimplant diseases. Implant Dent 2019;28:120-4. PUBMED | CROSSREF
27. Meyle J, Casado P, Fourmousis I, Kumar P, Quirynen M, Salvi GE. General genetic and acquired risk factors, and prevalence of peri-implant diseases - consensus report of working group 1. Int Dent J 2019;69 Suppl 2:3-6. PUBMED | CROSSREF
28. Al-Nawas B, Lambert F, Andersen SWM, Bornstein MM, Gahlert M, Jokstad A, et al. Group 3 ITI consensus report: materials and antiresorptive drug-associated outcomes in implant dentistry. Clin Oral Implants Res 2023;34 Suppl 26:169-76. PUBMED | CROSSREF
29. Heitz-Mayfield LJ, Aaboe M, Araujo M, Carrión JB, Cavalcanti R, Cionca N, et al. Group 4 ITI consensus report: risks and biologic complications associated with implant dentistry. Clin Oral Implants Res 2018;29 Suppl 16:351-8. PUBMED | CROSSREF
30. Korsch M, Walther W. Peri-implantitis associated with type of cement: a retrospective analysis of different types of cement and their clinical correlation to the peri-implant tissue. Clin Implant Dent Relat Res 2015;17 Suppl 2:e434-43. PUBMED | CROSSREF
31. Sarmiento HL, Norton MR, Fiorellini JP. A classification system for peri-implant diseases and conditions. Int J Periodont Restor Dent 2016;36:699-705. PUBMED | CROSSREF

32. de Tapia B, Mozas C, Valles C, Nart J, Sanz M, Herrera D. Adjunctive effect of modifying the implant-supported prosthesis in the treatment of peri-implant mucositis. J Clin Periodontol 2019;46:1050-60. PUBMED | CROSSREF

33. Derks J, Schaller D, Håkansson J, Wennström JL, Tomasi C, Berglundh T. Effectiveness of implant therapy analyzed in a Swedish population: prevalence of peri-implantitis. J Dent Res 2016;95:43-9. PUBMED | CROSSREF

34. Yi Y, Koo KT, Schwarz F, Ben Amara H, Heo SJ. Association of prosthetic features and peri-implantitis: a cross-sectional study. J Clin Periodontol 2020;47:392-403. PUBMED | CROSSREF

35. Kim HJ, Karasan D, Park K, Kwon HB, Han JS, Lee JH. Abutment margin levels and residual cement occurrence in cement-retained implant restorations: an observational study. Clin Oral Implants Res 2023;34:33-41. PUBMED | CROSSREF

36. Giovannoli JL, Roccuzzo M, Albouy JP, Duffau F, Lin GH, Serino G. Local risk indicators - consensus report of working group 2. Int Dent J 2019;69 Suppl 2:7-11. PUBMED | CROSSREF

37. Vervaeke S, Matthys C, Nassar R, Christiaens V, Cosyn J, De Bruyn H. Adapting the vertical position of implants with a conical connection in relation to soft tissue thickness prevents early implant surface exposure: a 2-year prospective intra-subject comparison. J Clin Periodontol 2018;45:605-12. PUBMED | CROSSREF

38. Thoma DS, Cosyn J, Fickl S, Jensen SS, Jung RE, Raghoebar GM, et al. Soft tissue management at implants: Summary and consensus statements of group 2. The 6th EAO consensus conference 2021. Clin Oral Implants Res 2021;32 Suppl 21:174-80. PUBMED | CROSSREF

39. Lin GH, Chan HL, Wang HL. The significance of keratinized mucosa on implant health: a systematic review. J Periodontol 2013;84:1755-67. PUBMED | CROSSREF

40. Giannobile WV, Jung RE, Schwarz F; Groups of the 2nd Osteology Foundation Consensus Meeting. Evidence-based knowledge on the aesthetics and maintenance of peri-implant soft tissues: osteology foundation consensus report part 1-effects of soft tissue augmentation procedures on the maintenance of peri-implant soft tissue health. Clin Oral Implants Res 2018;29 Suppl 15:7-10. PUBMED | CROSSREF

41. Renvert S, Hirooka H, Polyzois I, Kelekis-Cholakis A, Wang HL; Working Group 3. Diagnosis and non-surgical treatment of peri-implant diseases and maintenance care of patients with dental implants - consensus report of working group 3. Int Dent J 2019;69:12-7. PUBMED | CROSSREF

42. Lindhe J, Meyle J; Group D of European Workshop on Periodontology. Peri-implant diseases: consensus report of the sixth European workshop on periodontology. J Clin Periodontol 2008;35:282-5. PUBMED | CROSSREF

43. Berglundh T, Armitage G, Araujo MG, Avila-Ortiz G, Blanco J, Camargo PM, et al. Peri-implant diseases and conditions: consensus report of workgroup 4 of the 2017 World Workshop on the classification of periodontal and peri-implant diseases and conditions. J Clin Periodontol 2018;45 Suppl 20:S286-91. PUBMED | CROSSREF

44. Renvert S, Roos-Jansåker AM, Claffey N. Non-surgical treatment of peri-implant mucositis and peri-implantitis: a literature review. J Clin Periodontol 2008;35:305-15. PUBMED | CROSSREF

45. Schwarz F, John G, Hegewald A, Becker J. Non-surgical treatment of peri-implant mucositis and peri-implantitis at zirconia implants: a prospective case series. J Clin Periodontol 2015;42:783-8. PUBMED | CROSSREF

46. Klinge B, Meyle J; Working Group 2. Peri-implant tissue destruction. The third EAO consensus conference 2012. Clin Oral Implants Res 2012;23 Suppl 6:108-10. PUBMED | CROSSREF

47. Korello K, Eickholz P, Zuhr O, Ratka C, Petsos H. In vitro efficacy of non-surgical and surgical implant surface decontamination methods in three different defect configurations in the presence or absence of a suprastructure. Clin Implant Dent Relat Res 2023;25:549-63. PUBMED | CROSSREF

48. Park SH, Song YW, Cha JK, Lee JS, Kim YT, Shin HS, et al. Adjunctive use of metronidazole-minocycline ointment in the nonsurgical treatment of peri-implantitis: a multicenter randomized controlled trial. Clin Implant Dent Relat Res 2021;23:543-54. PUBMED | CROSSREF

49. Ardila CM, Bedoya-García JA, Arrubla-Escobar DE. Antibiotic resistance in periodontitis patients: a systematic scoping review of randomized clinical trials. Oral Dis 2023;29:2501-11. PUBMED | CROSSREF

50. Liñares A, Pico A, Blanco C, Blanco J. Adjunctive systemic metronidazole to nonsurgical therapy of peri-implantitis with intrabony defects: a retrospective case series study. Int J Oral Maxillofac Implants 2019;34:1237-45. PUBMED | CROSSREF

51. Yoon SW, Kim MJ, Paeng KW, Yu KA, Lee CK, Song YW, et al. Efficacy of local minocycline agents in treating peri-implantitis: an experimental in vivo study in beagle dogs. Pharmaceutics 2020;12:1016. PUBMED | CROSSREF

52. Yoon SW, Kim MJ, Paeng KW, Yu KA, Lee CK, Song YW, et al. Locally applied slow-release of minocycline microspheres in the treatment of peri-implant mucositis: an experimental in vivo study. Pharmaceutics 2020;12:668. PUBMED | CROSSREF

53. Han JW, Han JW, Pyo SW, Kim S. Impact of profile angle of CAD-CAM abutment on the marginal bone loss of implant-supported single-tooth posterior restorations. J Prosthet Dent. Forthcoming 2023. PUBMED | CROSSREF

54. Vázquez Álvarez R, Pérez Sayáns M, Gayoso Diz P, García García A. Factors affecting peri-implant bone loss: a post-five-year retrospective study. Clin Oral Implants Res 2015;26:1006-14. PUBMED | CROSSREF

55. Ramanauskaite A, Sader R. Esthetic complications in implant dentistry. Periodontol 2000 2022;88:73-85. PUBMED | CROSSREF

56. Katafuchi M, Weinstein BF, Leroux BG, Chen YW, Daubert DM. Restoration contour is a risk indicator for peri-implantitis: a cross-sectional radiographic analysis. J Clin Periodontol 2018;45:225-32. PUBMED | CROSSREF

57. Strauss FJ, Park JY, Lee JS, Schiavon L, Smirani R, Hitz S, et al. Wide restorative emergence angle increases marginal bone loss and impairs integrity of the junctional epithelium of the implant supracrestal complex: a preclinical study. J Clin Periodontol 2024;51:1677-87. PUBMED | CROSSREF

58. Jeong JS, Chang M. Food impaction and periodontal/peri-implant tissue conditions in relation to the embrasure dimensions between implant-supported fixed dental prostheses and adjacent teeth: a cross-sectional study. J Periodontol 2015;86:1314-20. PUBMED | CROSSREF

59. Schwarz F, Jepsen S, Obreja K, Galarraga-Vinueza ME, Ramanauskaite A. Surgical therapy of peri-implantitis. Periodontol 2000 2022;88:145-81. PUBMED | CROSSREF

60. Berglundh T, Wennström JL, Lindhe J. Long-term outcome of surgical treatment of peri-implantitis. A 2–11-year retrospective study. Clin Oral Implants Res 2018;29:404-10. PUBMED | CROSSREF

61. Koo KT, Khoury F, Keeve PL, Schwarz F, Ramanauskaite A, Sculean A, et al. Implant surface decontamination by surgical treatment of periimplantitis: a literature review. Implant Dent 2019;28:173-6. PUBMED | CROSSREF

62. Cha JK, Paeng K, Jung UW, Choi SH, Sanz M, Sanz-Martín I. The effect of five mechanical instrumentation protocols on implant surface topography and roughness: a scanning electron microscope and confocal laser scanning microscope analysis. Clin Oral Implants Res 2019;30:578-87. PUBMED | CROSSREF

63. Sirinirund B, Garaicoa-Pazmino C, Wang HL. Effects of mechanical instrumentation with commercially available instruments used in supportive peri-implant therapy: an in vitro study. Int J Oral Maxillofac Implants 2019;34:1370-8. PUBMED | CROSSREF

64. Francis S, Iaculli F, Perrotti V, Piattelli A, Quaranta A. Titanium surface decontamination: a systematic review of in vitro comparative studies. Int J Oral Maxillofac Implants 2022;37:76-84. PUBMED | CROSSREF

65. Froum SJ, Froum SH, Rosen PS. A regenerative approach to the successful treatment of peri-implantitis: a consecutive series of 170 implants in 100 patients with 2- to 10-year follow-up. Int J Periodont Restor Dent 2015;35:857-63. PUBMED | CROSSREF

66. Monje A, Amerio E, Cha JK, Kotsakis G, Pons R, Renvert S, et al. Strategies for implant surface decontamination in peri-implantitis therapy. Int J Oral Implantol (Berl) 2022;15:213-48. PUBMED

67. Roccuzzo M, Mirra D, Pittoni D, Ramieri G, Roccuzzo A. Reconstructive treatment of peri-implantitis infrabony defects of various configurations: 5-year survival and success. Clin Oral Implants Res 2021;32:1209-17. PUBMED | CROSSREF

68. Suarez F, Monje A, Galindo-Moreno P, Wang HL. Implant surface detoxification: a comprehensive review. Implant Dent 2013;22:465-73. PUBMED | CROSSREF

69. Stavropoulos A, Bertl K, Eren S, Gotfredsen K. Mechanical and biological complications after implantoplasty-a systematic review. Clin Oral Implants Res 2019;30:833-48. PUBMED | CROSSREF

70. Burgueño-Barris G, Camps-Font O, Figueiredo R, Valmaseda-Castellón E. The influence of implantoplasty on surface roughness, biofilm formation, and biocompatibility of titanium implants: a systematic review. Int J Oral Maxillofac Implants 2021;36:e111-9. PUBMED | CROSSREF

71. Mombelli A, Hashim D, Cionca N. What is the impact of titanium particles and biocorrosion on implant survival and complications? A critical review. Clin Oral Implants Res 2018;29 Suppl 18:37-53. PUBMED | CROSSREF

72. Bertl K, Isidor F, von Steyern PV, Stavropoulos A. Does implantoplasty affect the failure strength of narrow and regular diameter implants? A laboratory study. Clin Oral Investig 2021;25:2203-11. PUBMED | CROSSREF

73. Monje A, Pons R, Insua A, Nart J, Wang HL, Schwarz F. Morphology and severity of peri-implantitis bone defects. Clin Implant Dent Relat Res 2019;21:635-43. PUBMED | CROSSREF

74. Ramanauskaite A, Fretwurst T, Schwarz F. Efficacy of alternative or adjunctive measures to conventional non-surgical and surgical treatment of peri-implant mucositis and peri-implantitis: a systematic review and meta-analysis. Int J Implant Dent 2021;7:112. PUBMED | CROSSREF

75. Perussolo J, Souza AB, Matarazzo F, Oliveira RP, Araújo MG. Influence of the keratinized mucosa on the stability of peri-implant tissues and brushing discomfort: a 4-year follow-up study. Clin Oral Implants Res 2018;29:1177-85. PUBMED | CROSSREF

76. Gharpure AS, Latimer JM, Aljofi FE, Kahng JH, Daubert DM. Role of thin gingival phenotype and inadequate keratinized mucosa width (<2 mm) as risk indicators for peri-implantitis and peri-implant mucositis. J Periodontol 2021;92:1687-96. PUBMED | CROSSREF

77. Meffert RM. How to treat ailing and failing implants. Implant Dent 1992;1:25-33. PUBMED | CROSSREF

78. Scarano A, Carinci F, Quaranta A, Iezzi G, Piattelli M, Piattelli A. Correlation between implant stability quotient (ISQ) with clinical and histological aspects of dental implants removed for mobility. Int J Immunopathol Pharmacol 2007;20:33-6. PUBMED | CROSSREF

79. Stoichkov B, Kirov D. Analysis of the causes of dental implant fracture: a retrospective clinical study. Quintessence Int 2018;49:279-86. PUBMED | CROSSREF

80. Yu HC, Kim YK. Fractures of implant fixtures: a retroscccpective clinical study. Maxillofac Plast Reconstr Surg 2020;42:13. PUBMED | CROSSREF

81. Decker AM, Sheridan R, Lin GH, Sutthiboonyapan P, Carroll W, Wang HL. A prognosis system for periimplant diseases. Implant Dent 2015;24:416-21. PUBMED

82. Ravidà A, Siqueira R, Di Gianfilippo R, Kaur G, Giannobile A, Galindo-Moreno P, et al. Prognostic factors associated with implant loss, disease progression or favorable outcomes after peri-implantitis surgical therapy. Clin Implant Dent Relat Res 2022;24:222-32. PUBMED | CROSSREF

83. Heitz-Mayfield LJA, Heitz F, Lang NP. Implant disease risk assessment IDRA-a tool for preventing peri-implant disease. Clin Oral Implants Res 2020;31:397-403. PUBMED | CROSSREF

84. Monje A, Aranda L, Diaz KT, Alarcón MA, Bagramian RA, Wang HL, et al. Impact of maintenance therapy for the prevention of peri-implant diseases: a systematic review and meta-analysis. J Dent Res 2016;95:372-9. PUBMED | CROSSREF

85. Monje A, Wang HL, Nart J. Association of preventive maintenance therapy compliance and peri-implant diseases: a cross-sectional study. J Periodontol 2017;88:1030-41. PUBMED | CROSSREF

86. Lee SB, Lee BA, Choi SH, Kim YT. Long-term outcomes after peri-implantitis treatment and their influencing factors: a retrospective study. J Periodontal Implant Sci 2022;52:194-205. PUBMED | CROSSREF

87. Costa FO, Costa AM, Ferreira SD, Lima RPE, Pereira GHM, Cyrino RM, et al. Long-term impact of patients' compliance to peri-implant maintenance therapy on the incidence of peri-implant diseases: an 11-year prospective follow-up clinical study. Clin Implant Dent Relat Res 2023;25:303-12. PUBMED | CROSSREF

88. Echeverría JJ, Echeverría A, Caffesse RG. Adherence to supportive periodontal treatment. Periodontol 2000 2019;79:200-9. PUBMED | CROSSREF

89. Heitz-Mayfield LJA, Salvi GE. Peri-implant mucositis. J Clin Periodontol 2018;45 Suppl 20:S237-45. PUBMED | CROSSREF

90. Berglundh T, Lindhe J. Dimension of the periimplant mucosa. Biological width revisited. J Clin Periodontol 1996;23:971-3. PUBMED | CROSSREF

91. Lindhe J, Berglundh T. The interface between the mucosa and the implant. Periodontol 2000 1998;17:47-54. PUBMED | CROSSREF

92. Heitz-Mayfield LJA, Salvi GE. Peri-implant mucositis. J Periodontol 2018;89 Suppl 1:S257-66. PUBMED | CROSSREF

93. Seo H, Lee BA, Lim H, Yoon JH, Kim YT. The socioeconomic impact of Korean dental health insurance policy on the elderly: a nationwide cohort study in South Korea. J Periodontal Implant Sci 2019;49:248-57. PUBMED | CROSSREF

94. Park YS, Lee BA, Choi SH, Kim YT. Evaluation of failed implants and reimplantation at sites of previous dental implant failure: survival rates and risk factors. J Periodontal Implant Sci 2022;52:230-41. PUBMED | CROSSREF