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Peri-implantitis: risk factors, prevention and current treatment strategies

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ABSTRACT

Peri-implantitis has become a major biological problem in modern dental implantology. This disease is the result of a chronic inflammatory reaction, which attacks the soft and hard tissues around the implant. This condition is characterized by continuous inflammation of the mucosa around the implant, which gradually leads to the loss of supporting alveolar bone. As dental implants have shifted from a niche solution to a widely used option for tooth loss, the incidence of peri-implant diseases has increased. This is a serious obstacle to achieving long-term clinical success. The causes of this disease are complex and include the interaction of harmful bacterial biofilm, the body's immune response, and various local and systemic risk factors. Early diagnosis is crucial - recognizing the disease at an early stage allows for the implementation of treatment strategies relied on preventing bone loss and complete implant failure. This comprehensive literature review summarizes current evidence on causes, risk factors, and modern methods of prevention and treatment. Systematic searches of databases such as PubMed and Scopus focused on high-quality evidence from the last two decades. The findings indicate that the main factors which contribute to the occurrence of this disease are: inadequate oral hygiene, smoking, a history of periodontitis, and general problems such as diabetes. Treatment methods include mechanical wound debridement and advanced regenerative surgery using materials such as platelet-rich fibrin (PRF). No specific gold standard has yet been established. This review highlights the need for care to ensure the success of dental implants.

Keywords: peri-implantitis, dental implants, risk factors, prevention, regenerative therapy

1. INTRODUCTION

In today's field of restorative dentistry, dental implants have fundamentally changed the treatment of tooth loss. They provide functional and aesthetic predictability, which was previously impossible (Derks & Tomasi, 2015; Berglundh et al., 2018). Thanks to extensive research into implant design, implant surface and texture, and surgical methods, success rates are very high (Schwarz et al., 2018; Mombelli et al., 2012). However, with the widespread use of implant therapy,

biological complications, especially peri-implant diseases, have become more recognizable (Heitz-Mayfield, 2008; Renvert & Quirynen, 2015). These diseases are divided into two main categories: peri-implant mucositis and peri-implantitis (Berglundh et al., 2018). Peri-implant mucositis is a reversible inflammation located in the mucosa, whereas peri-implantitis is characterized by a more destructive, progressive inflammation leading to the loss of supporting bone (Derks & Tomasi, 2015; Schwarz et al., 2018). If left untreated, destructive bone loss can ultimately lead to implant failure due to loss of osseointegration (Schwarz et al., 2018; Mombelli et al., 2012).

The cause of peri-implantitis is essentially the accumulation of a diverse bacterial biofilm on the implant surface, which causes local inflammation (Heitz-Mayfield, 2008; Renvert & Quirynen, 2015). Studies show that the microbiological profile in these cases often includes pathogens associated with chronic periodontitis. This highlights the link between periodontal health and implant stability (Salvi et al., 2017). When an infection occurs, the body's immune system releases various substances that worsen tissue damage (Heitz-Mayfield, 2008). Other factors, such as patients' behaviors like smoking and oral hygiene, as well as prosthetic problems like excess cement or excessive bite forces, can increase the risk of bone loss (Ferreira et al., 2006; Salvi et al., 2017; Costa et al., 2012; Qian et al., 2012). With the ever-increasing number of implants being placed all over the world, it is becoming more and more important to understand how to prevent and treat peri-implantitis. This understanding has become a key point in modern dental practice (Mombelli et al., 2012; Costa et al., 2012). The purpose of this review is to summarize the latest research to provide solid evidence-based guidance for the effective treatment of peri-implantitis (Schwarz et al., 2018; Canellas et al., 2019).

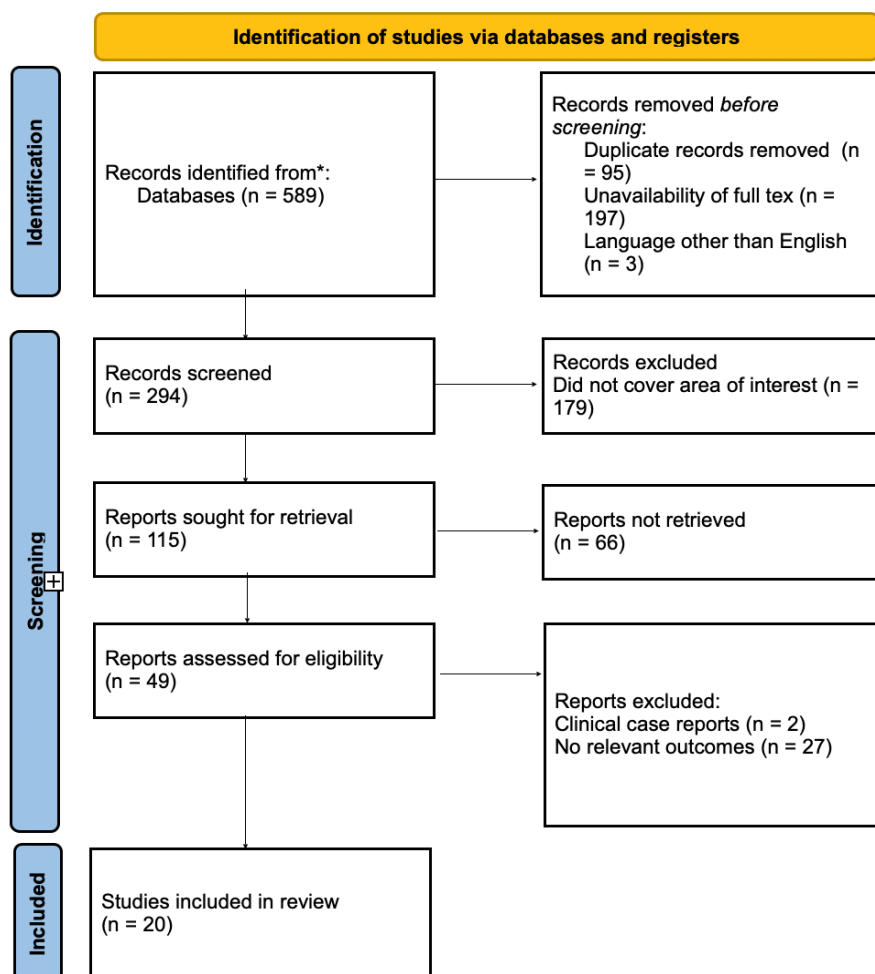


Figure 1. PRISMA Flow Diagram

2. REVIEW METHODS

To provide a detailed overview of the current treatment of peri-implantitis, a narrative literature review was conducted, focusing on causes, risk assessment, prevention, and treatment options. Systematic searches of electronic databases such as PubMed/MEDLINE,

Scopus, and Google Scholar were conducted to find reviewed articles mainly from 2000 to 2024. The search included keywords such as peri-implantitis, risk indicators, implant bone loss, regenerative therapy, biofilm, and implant maintenance. These terms were combined with Boolean operators (AND, OR) to ensure comprehensive search results.

High quality evidence from systematic reviews, meta-analyses and clinical trials (RCTs) was considered. We also analyzed consensus reports and statements from global dental groups to determine current diagnostic standards and trends. Studies that were not conducted in English, did not meet clear diagnostic criteria, or included only animal studies, were excluded. Data included aspects such as study design, patient sample size, and main clinical outcomes, including changes in probing depth (PD), bleeding on probing (BOP), and radiographic bone level. Thanks to this approach, it was possible to obtain an accurate and scientifically justified summary of the current clinical status. The article screening process followed the PRISMA guidelines (Figure 1).

3. RESULTS AND DISCUSSION

Definition and Classification of Peri-implant Diseases

The current classification of peri-implant diseases was formally set during the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases. This agreement provides clear diagnostic criteria for both clinical practice and research. Peri-implantitis is defined as inflammation of the soft tissues surrounding the implant (Berglundh et al., 2018). It is characterized by local redness, swelling, and BOP (Lang & Berglundh, 2011). The most important thing about mucositis is that it can be reversed by removing the cause of the problem. As a result, the tissues can heal (Costa et al., 2012).

On the other hand, peri-implantitis is characterized by destructive inflammation involving both the mucosa and the supporting bone (Derks & Tomasi, 2015; Schwarz et al., 2018). Diagnosis includes signs of inflammation (BOP and/or pus), increased probing depth, and bone loss beyond what is considered normal after implant placement (Lang & Berglundh, 2011; Fransson et al., 2010). The change from mucositis to peri-implantitis occurs as a result of biofilm maturation and the body's inflammatory response (Heitz-Mayfield, 2008; Renvert & Quirynen, 2015). That's why early diagnosis of mucositis is a key preventive measure against irreversible bone loss (Costa et al., 2012). Physicians need to be aware that differences between studies may affect the incidence. These differences also impact disease severity in different patient groups (Derks & Tomasi, 2015; Berglundh et al., 2018; Fransson et al., 2010).

Etiology and Pathogenesis of Peri-implantitis

The causes of peri-implantitis are mainly microbiological factors. Especially the growth of harmful biofilm on the surface of the dental implant (Heitz-Mayfield, 2008; Renvert & Quirynen, 2015). The microbiological composition in peri-implantitis is complex and often includes anaerobic Gram-negative bacteria such as *Porphyromonas gingivalis*, *Treponema denticola*, and *Tannerella forsythia* (Salvi et al., 2017). Various factors released by bacteria trigger a strong immune response in the host organism (Heitz-Mayfield, 2008; Renvert & Quirynen, 2015). As a result of pathogenesis, a significant increase in the concentration of proinflammatory cytokines such as interleukin-1 beta (IL-1 β), tumor necrosis factor-alpha (TNF- α), and matrix metalloproteinases (MMPs) is observed (Heitz-Mayfield, 2008). These substances contribute to the breakdown of soft tissues around the implant and stimulate osteoclast activity, which leads to rapid bone loss.

Dental implants lack a periodontal ligament (PDL), so they are much more susceptible to rapid bone loss than natural teeth (Schwarz et al., 2018; Qian et al., 2012). In natural teeth, the periodontal ligament acts as a biological and physical barrier that limits inflammation. The periodontal ligament prevents inflammation from spreading more easily to the bone (Schwarz et al., 2018; Renvert & Quirynen, 2015). Genetic susceptibility and a history of periodontitis influence the body's inflammatory response (Ferreira et al., 2006; Salvi et al., 2017). You should also pay attention to mechanical problems, such as overbite. Excessive pressure on the implant can weaken the implant-to-bone interface. This ultimately leads to increased bone loss. Bacterial plaque also contributes to increased bone loss (Qian et al., 2012). The interaction between biological infection and implant highlights the importance of accurate diagnosis.

Risk Factors for Peri-implantitis

Identifying and managing risk factors is crucial to the long-term success of implant therapy (Renvert & Quirynen, 2015; Ferreira et al., 2006). These factors can be generally categorized as patient-related, implant-related, or prosthetic categories (Figuro et al., 2014).

In the patient-related group, the most important factor that can be changed is poor oral hygiene (Ferreira et al., 2006; Costa et al., 2012). Plaque buildup leads directly to biofilm-induced inflammation (Heitz-Mayfield, 2008; Mombelli et al., 2012). Another important indicator of peri-implantitis is a history of periodontitis. These patients often have pre-existing inflammation and microbial

communities (Heitz-Mayfield, 2008; Salvi et al., 2017). Smoking is a serious threat. Nicotine disrupts blood flow and the function of host cells such as osteoblasts and fibroblasts. Smoking makes healing difficult and accelerates bone loss (Salvi et al., 2017; Costa et al., 2012; Mombelli et al., 2012). Systemic diseases, especially poorly controlled diabetes, weaken the immune system and slow wound healing (Salvi et al., 2017; Costa et al., 2012).

Factors related to the implant and prosthesis are also very important. The rough surface of the implant promotes initial osseointegration, but is also difficult to clean (Heitz-Mayfield, 2008; Figuero et al., 2014). Improperly placed implants can cause areas where plaque accumulates, making it difficult to clean thoroughly (Figuero et al., 2014; Qian et al., 2012). The amount of keratinized tissue around the implant affects plaque control. Insufficient keratinized tissue often leads to increased inflammation (Costa et al., 2012; Mombelli et al., 2012). In the case of prosthetic agents, too much submucosal cement can irritate the area and cause rapid, local infection (Fransson et al., 2010). Poorly designed prosthetics can make cleaning between teeth difficult, and excessive force on the implant can increase the risk of bone loss (Figuero et al., 2014; Fransson et al., 2010; Qian et al., 2012).

Diagnosis of Peri-implantitis

Early and accurate diagnosis is crucial for the preservation of dental implants (Miron et al., 2017; Lang & Berglundh, 2011). The diagnostic process combines clinical assessment with radiological control. Periodontal probing is an essential clinical tool for detecting changes in probing depth (PD) (Lang & Berglundh, 2011). Implants do not have a periodontal ligament, so clinicians must compare PD measurements with baseline values after implantation. This enables detection of any pathological changes (Berglundh et al., 2018; Lang & Berglundh, 2011). Bleeding on probing (BOP) is a sensitive sign of inflammation around the implant, while pus indicates an active infection (Lang & Berglundh, 2011; Fransson et al., 2010). To assess the supporting bone, it is necessary to take high-quality X-rays of the apical region. A confirmed increase in bone loss compared to previous images indicates peri-implantitis (Berglundh et al., 2018; Fransson et al., 2010). Correct diagnosis is the only way to distinguish mucositis from peri-implantitis. This allows for the rapid implementation of appropriate treatment (Lang & Berglundh, 2011). This stage is considered to be one of the most important in the treatment of peri-implantitis in modern dentistry.

Prevention of Peri-implantitis

The best treatment strategy for peri-implantitis is primary prevention (Borie et al., 2015; Costa et al., 2012). The patient should be informed about the need for further follow-up visits during the consultation. The patient must be under constant medical care because no implant has a lifetime warranty. Preventive measures should be started already at the stage of treatment planning in the dental office. Patients' education is crucial. They should receive detailed training in oral hygiene, especially in the use of specialized interdental brushes and dental floss around the implant (Ferreira et al., 2006; Costa et al., 2012). After treatment, it is extremely important to follow a professional follow-up schedule to detect any inflammatory changes early (Costa et al., 2012; Monje et al., 2016). Imaging studies should be performed periodically for monitoring. Managing factors such as smoking and blood sugar control in people with diabetes is also very important (Salvi et al., 2017; Costa et al., 2012). From a clinical perspective, it is important to ensure precise implant placement and use prostheses that are easy to clean and prevent excessive cement accumulation. This can prevent inflammation (Figuero et al., 2014; Qian et al., 2012). Maintenance therapy is the most effective way to ensure the long-term health of dental implants (Monje et al., 2016).

Treatment Strategies for Peri-implantitis

The goal of treating peri-implantitis is to prevent the disease from worsening and to stabilize the implant-bone connection (Schwarz et al., 2018; Romeo et al., 2005). Treatment is typically divided into non-surgical and surgical stages. The first line of defense is non-surgical treatment. This treatment involves mechanical cleaning of the implant surface using specialized non-metallic curettes (plastic or titanium) or ultrasonic devices (Figuero et al., 2014). Lasers (photodynamic therapy) or topical/systemic antibiotics may help reduce the number of microorganisms (Figuero et al., 2014; Romeo et al., 2005). Although non-surgical therapy is effective for mucositis, it is often ineffective for advanced peri-implantitis because it is difficult to thoroughly clean the rough implant surfaces (Mombelli et al., 2012; Romeo et al., 2005).

A more radical method is surgical access (Schwarz et al., 2010). Surgery involves reducing the pocket depth by removing the inflammatory tissue and reshaping the bone. This makes cleaning easier (Romeo et al., 2005). Surgery aims to rebuild lost bone tissue

using grafts and membranes. It is considered to be a very good method, but its disadvantage is the high cost (Choukroun et al., 2001; Borie et al., 2015; Monje et al., 2016).

Recently, there has been an increasing interest in biological materials such as Platelet-Rich Fibrin (PRF), which releases growth factors that support soft tissue healing and bone regeneration (Miron et al., 2017). These are very good materials that constitute an alternative in treatment. PRF has special properties in areas undergoing surgery. It accelerates healing and improves the predictability of regenerative outcomes (Canellas et al., 2019). The choice of treatment method usually depends on the degree of bone loss and the specific nature of the lesion (Schwarz et al., 2018). It is important to choose the right treatment method. This can increase the likelihood of success (table 1).

Table 1. Summary of the main findings regarding peri-implantitis risk factors, prevention and treatment strategies

Author	Topic	Clinical Outcome	Key Findings
Ferreira et al., (2006)	Risk factors	Peri-implantitis risk	Inadequate oral hygiene has been recognized as one of the strongest modifiable risk factors for the development of peri-implant disease.
Costa et al., (2012)	Prevention	Implant maintenance	Regular preventive treatments significantly reduced the incidence of peri-implant diseases.
Salvi et al., (2017)	Risk factors	Peri-implantitis development	Smoking, diabetes and history of periodontitis increase the susceptibility to peri-implantitis.
Heitz-Mayfield, (2008)	Etiology	Biofilm-induced inflammation	The accumulation of pathogenic biofilm is the main cause of peri-implant inflammation and bone loss.
Renvert & Quirynen, (2015)	Risk indicators	Disease progression	The development of peri-implantitis is influenced by numerous local and patient-related factors.
Lang & Berglundh, (2011)	Diagnosis	Clinical assessment	Bleeding on probing and increased depth of probing are important diagnostic indicators of peri-implant disease.
Berglundh et al., (2018)	Classification	Disease definition	Current diagnostic criteria have been established to distinguish peri-implant mucositis from peri-implantitis.
Figuero et al., (2014)	Prevention / Treatment	Plaque control	Correct implant design and effective plaque control play an important role in disease prevention.
Romeo et al., (2005)	Surgical treatment	Advanced peri-implantitis	Resective surgery can reduce pocket depth and improve implant retention.
Schwarz et al., (2010)	Surgical therapy	Bone defect management	In advanced cases of peri-implantitis, surgical intervention is often necessary.

Miron et al., (2017)	Regenerative therapy	Soft tissue healing	Platelet-rich fibrin (PRF) accelerates healing and supports tissue regeneration.
Canellas et al., (2019)	Regenerative therapy	Bone regeneration	PRF improves regenerative outcomes in oral surgery.
Monje et al., (2016)	Prevention	Long-term implant survival	Maintenance therapy is essential to prevent recurrence of peri-implant disease.
Qian et al., (2012)	Mechanical factors	Marginal bone loss	Occlusal overload and prosthetic complications may contribute to bone loss around the implant.
Mombelli et al., (2012)	Epidemiology	Disease prevalence	The increasingly common use of implants is associated with an increase in the incidence of peri-implantitis.

4. CONCLUSION

Peri-implantitis remains one of the most difficult challenges in modern restorative dentistry. This is a complex problem that requires comprehensive solutions focusing on early diagnosis and effective prevention. There are many surgical and non-surgical treatment options available, but there is no single, universally accepted gold standard. Both methods can be effective. Success depends on the degree of bone loss and the patient's risk factors. In the future, high-quality research will be necessary to develop treatment protocols. The increasing incidence of peri-implantitis highlights the importance of interdisciplinary collaboration between periodontists, prosthodontists, oral surgeons, and dental hygienists. Individual treatment planning is considered the most important. It is based on an assessment of the risk for a given patient. This must be standard practice. Changes in implant surface technology, biomaterials, and host-modifying therapies may increase treatment efficacy and reduce complications. Patients must follow post-operative care protocols. This remains a key factor influencing the long-term survival of the implant and the stability of the tissues surrounding the implant.

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Data and materials availability

All data associated with this study will be available based on the reasonable request to corresponding author.

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