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Review

Peri-implantitis: a comprehensive review of recent findings

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DISCLOSURE: **ALL AUTHORS REPORT NO CONFLICTS OF INTEREST RELEVANT TO THIS ARTICLE.**

ABSTRACT

Peri-implantitis is a growing concern as dental implants become increasingly popular. This review paper aims to present the current understanding of peri-implant disease and provide insights into its management and prevention. Material and Methods: The study followed PRISMA guidelines and conducted an extensive electronic search for relevant articles. Only systematic reviews published in Q1 and Q2 journals were considered. Results: Eighteen systematic reviews have been selected from the 63 initial studies. The prevalence of peri-implantitis is estimated at around 19.53% of patients with implants and 12.53% of implants placed. Specific bacteria and MMP-8 levels have been associated with peri-implantitis, highlighting potential diagnostic markers. Conclusions: The review emphasized the need for consensus in research to estimate the epidemiological parameters of peri-implantitis accurately. Additionally, the adjunctive use of local antibiotics showed promising results in improving probing pocket depth and bleeding on probing compared to surgical treatment alone. Overall, this paper provides a comprehensive overview of the current knowledge on peri-implantitis and emphasizes the importance of precise diagnostic markers and effective treatment modalities.

INTRODUCTION

Dental implants have become a cornerstone in modern restorative dentistry, providing a durable and aesthetically pleasing solution for replacing missing teeth. Clinical applications of dental implants span diverse scenarios, from single-tooth replacements to complex full-arch rehabilitations. While in the early years of implantology, there was much focus on improving osteointegration and primary stability, to date, enormous efforts have been made to try to understand how to maintain osteointegrated implants and how to prevent or treat peri-implantitis.

Peri-implantitis is a pathological condition affecting dental implants, and as dental implant therapy continues to gain popularity as a reliable and aesthetically pleasing solution for tooth replacement, the prevalence of peri-implantitis has also witnessed a parallel rise. This multifactorial inflammatory condition involves the progressive loss of supporting bone around dental implants, jeopardizing their long-term stability and success (1). Given the complexity of peri-implantitis, a thorough understanding of its etiology, pathogenesis, accurate diagnostic methods, and effective treatment modalities is imperative for clinicians and researchers alike. The etiological landscape of peri-implantitis is intricate, encompassing factors such as microbial colonization, host response, biomechanical issues, and systemic influences (1–5).

Peri-implantitis can be visualized in radiographic images, such as X-rays (RX), commonly used in dental implant assessments. The radiographic appearance of peri-implantitis typically involves changes in the bone around the implant. Furthermore, additional imaging modalities, such as cone-beam computed tomography (CBCT), may provide three-dimensional information about the extent of bone loss and help in treatment planning for cases of peri-implantitis.

The 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions defined peri-implantitis as “a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone” (6).

The impact of patient-related factors, including smoking habits, systemic diseases, and genetic predispositions, has been explored by Schwarz et al. (7), providing valuable insights into the host-mediated aspects of peri-implantitis.

Many efforts have been made, especially on the therapeutic front. Sanz-Sanchez et al. (8) and Tomasi and Derks delved into various treatment modalities, including nonsurgical interventions, antimicrobial agents, and regenerative approaches (9). These studies contribute to the ongoing efforts to establish evidence-based guidelines for managing peri-implantitis.

This review aims to clarify knowledge about peri-implant disease and try to draw a future perspective on its management and prevention. To obtain the broadest possible view, we have attempted to compare the oldest literature with the most recent systematic reviews to see every aspect of this disease from multiple perspectives.

MATERIALS AND METHODS

This study followed the PRISMA statement guidelines (2020). This systematic review was conducted according to the population, intervention, control and outcome (PICO) format. We analyzed systematic reviews involving patients affected by peri-implantitis, searching for what's new in the field of epidemiology, diagnosis, correlations, treatment, and outcome. The following inclusion and exclusion criteria were applied to conduct study selection.

Inclusion Criteria

- Systematic reviews and meta-analyses only
- Human studies
- Articles published exclusively in English

Exclusion Criteria

- In vitro studies, animal studies, retrospective studies, case reports, case series, literature reviews, systematic reviews without meta-analyses and meta-analyses without systematic reviews
- Non open-access article

Information Sources

Electronic research was performed through the MEDLINE (PubMed) database.

Search Strategy

The electronic search was conducted by two independent examiners to minimize reviewer biases, applying the following filters: date of publication starting 01/01/2020 up to the time of the search 20/12/2023, journal quartile including "Q1" and "Q2", and type of article including "systematic review" and "meta-analysis". The research on PubMed was conducted using the mesh term peri-implantitis.

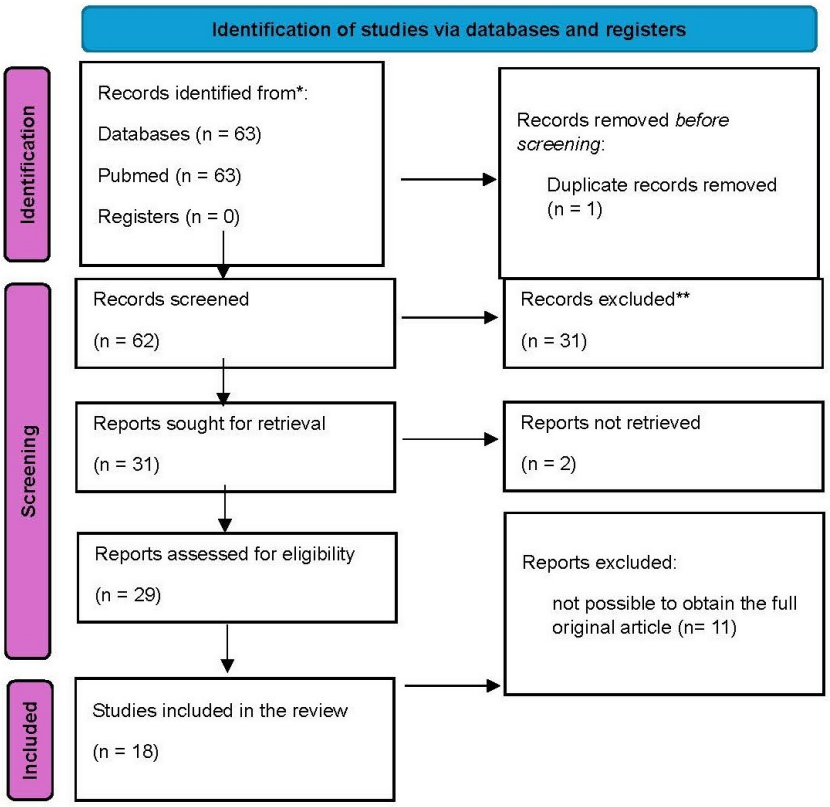
Study Selection

Titles deriving from the research previously described were reviewed by two examiners. In the case of disagreement, the two reviewers analyzed the title jointly to arrive at a final decision concerning inclusion or exclusion. Articles identified as helpful in answering the research question were selected to read the abstract. In the examination of the abstract, attention was paid to assessing the compliance of the study with the inclusion criteria. The selected studies were saved as a digital or paper version and submitted to a full-text analysis. In this way, only articles that conformed to the above criteria were included.

RESULTS

The electronic search initially produced 63 articles, and after a first reading of the titles, 1 article was deleted. After an analysis of the title and the abstract, the number of articles decreased to 29 (Table I).

Table I. *Initial electronic search and analysis.*



Starting with a full-text analysis, we found that 11 were not available in free access mode, so they were discarded. We have thus arrived at 18 systematic reviews, as shown in Table II.

Table II. *Articles selected for inclusion.*

PMID	Authors	Journal/Book	Journal quartile	Publication Year	DOI	N. of Studies
37508319	Baus-Domínguez M et al.	Antibiotics (Basel)	Q2	2023	10.3390/antibiotics12071223	14
35682086	Toledano-Osorio M et al.	Int J Environ Res Public Health	Q2	2022	10.3390/ijerph19116502	18
36551424	Grusovin MG et al.	Antibiotics (Basel)	Q2	2022	10.3390/antibiotics11121766	6
37296382	Barbato L et al.	BMC Oral Health	Q2	2023	10.1186/s12903-023-03058-z	16

32683389	Liu S et al.	Med Oral Patol Oral Cir Bucal	Q2	2020	10.4317/medoral.23633	7
36217689	Karlsson K et al.	J Clin Periodontol	Q1	2023	10.1111/jcpe.13732	16
37287463	López-Valverde N et al.	Front Cell Infect Microbiol	Q2	2023	10.3389/fcimb.2023.1149055	5
33487962	Saneja R et al.	J Indian Prosthodont Soc	Q2	2020	10.4103/jips.jips_144_20	11
34455016	Toledano M et al.	J Dent	Q1	2021	10.1016/j.jdent.2021.103790	12
37076816	Cheng J et al.	BMC Oral Health	Q2	2023	10.1186/s12903-023-02956-6	13
33562820	Roca-Millan E et al.	Viruses	Q1	2021	10.3390/v13020250	5
35207724	Dioguardi M et al.	J Pers Med	Q1	2022	10.3390/jpm12020235	7

10 papers were published in Q2 journals (source: Journal Citation Reports by Clarivate), while 8 were published in Q1 journals. 9 papers were published in 2023, 5 in 2022, 2 in 2021 and 2 in 2020.

Each analyzed systematic review deals with the issue of periimplantitis from a different point of view, since this paper aims to be a literature review, the aim was not so much to arrive at absolute truths but rather to provide a transversal knowledge of what is at present of this issue.

DISCUSSION

Prevalence

As Berglundh argued in 2002, the prevalence of peri-implantitis remains challenging to assess because data on implant BoP are rarely reported in various studies. The prevalence of peri-implantitis varies across studies and populations, reflecting the multifactorial nature of this condition. Recent systematic reviews and meta-analyses estimate the overall prevalence of peri-implantitis to range from 1% to 47%, depending on the definition criteria and follow-up periods employed in different investigations (10, 11). Such variations underscore the need for a standardized diagnostic framework and consistent reporting methodologies to accurately assess and compare peri-implantitis prevalence worldwide.

Understanding the prevalence of peri-implantitis is crucial for clinicians and researchers alike, as it emphasizes the necessity of preventive measures, early detection, and effective management strategies (12). As the population ages and the utilization of dental implants continues to rise, a comprehensive grasp of peri-implantitis prevalence becomes paramount for ensuring the long-term success of implant-supported restorations.

From the latest data of the systematic review made by Diaz et al., in which they analyzed 57 articles, the prevalence of periimplantitis is around 19.53% of patients who received implants and 12.53% of implants placed (13). In addition, the Diaz article highlighted the need for more accurate disease classification. It

recommended using consistent periodontal measurements based on the 2017 World Workshop's definition of peri-implant diseases for future studies.

The review also discussed the limitations of the current definition, severity, and prevalence of peri-implantitis, emphasizing the need for consensus in research to estimate its epidemiological parameters accurately. The outcome of his study suggested that individual risk factors, follow-up time, and the use of probing depth as a diagnostic criterion influenced the prevalence of peri-implantitis. The review recommended the use of more consistent periodontal measurements and the adoption of standardized diagnostic criteria for accurate estimation of peri-implantitis prevalence. In conclusion, the review underscored the importance of identifying precise diagnostic markers for improved disease classification and accurate estimation of peri-implantitis prevalence. Trying to track a guideline through this data is even more complicated when we try to assess the prevalence and diagnosis criteria on the short and ultra-short (14), implants positioned in free fibula flaps (15), or zygomatic implants (16, 17).

Correlations

Over the years, the etiology of periimplantitis has been extensively investigated. In addition to the traditional periodontal bacteria, correlations have been sought with other microorganisms that could better explain the rapid evolution of this disease and the degree of destruction of the peri-implant tissues.

Elisabet Roca-Millan et al., in their systematic review, aimed to investigate the potential association between the presence of Epstein–Barr virus (EBV) and the development of periimplantitis (18). The analysis encompassed five cross-sectional and case-control studies. It concluded that no statistically significant association was found between the prevalence of EBV in the peri-implant sulcus and the presence of peri-implantitis, and the results did not support a significant link between EBV and peri-implantitis. Furthermore, the review emphasized the bidirectional interaction between EBV and bacterial periopathogens, suggesting that EBV may play a role in the initiation and progression of peri-implant tissue breakdown by contributing to the overgrowth and aggressiveness of bacteria. The findings underscored the need for further research to develop more effective treatments for peri-implantitis and to better understand the potential association between EBV and peri-implant diseases.

The research paper of Érika B S Carvalho et al. intended to investigate the differences in bacterial presence and count between peri-implantitis and peri-implant health/mucositis in systemically healthy human subjects (19). The study included 12 cross-sectional studies with 1233 participants and 1513 implants. The findings suggested that peri-implantitis was associated with the presence of specific bacteria, including *S. epidermidis, F. nucleatum, T. denticola, T. forsythia, P. intermedia,* and *P. gingivalis*. Conversely, the presence of *A. actinomycetemcomitans, S. aureus,* and *C. rectus* was not associated with peri-implantitis. Meta-analyses revealed strong associations between peri-implantitis and the presence of S. epidermidis and specific periodontopathogens.

Mario Dioguardi et al.'s systematic review aimed to identify the relationship between peri-implantitis inflammation indices and glycemic levels in patients with and without diabetes who have undergone dental implant treatments (20). The review included seven studies and revealed worse outcomes in patients with diabetes in the short period (six months) for peri-implantitis inflammation indices such as marginal bone loss, bleeding on probing, probing depth, and plaque index. The meta-analysis indicated a statistically significant difference in peri-implant inflammation indices between the control group and the diabetes group, particularly after a six-month follow-up. The review also highlighted the importance of considering individualized information from translational research and analyzing all risk factors to provide evidence-based treatment options in the era of personalized medicine. Factors affecting peri-implant health, such as high body mass

index, history of periodontal disease, oral hygiene, and smoking, were identified as important but not well-researched, especially in diabetic patients (21, 22). The review emphasized the need for standardized clinical and radiological indicators for peri-implant diseases and recommended longitudinal studies with globally accepted case definitions and monitoring of blood glucose levels for more homogeneous, quantitative data.

Markers

One of the most important factors in the management of peri-implantitis is timing. Several efforts have been made to identify the molecular markers associated with this disease and determine if they are. Some study investigates the potential use of salivary biomarkers for early detection of peri-implantitis by analyzing the levels of CXCL9 and CXCL14 in saliva samples of patients with and without peri-implantitis (23). Other studies investigated the correlation with miR-4484 expression, identifying it as a biomarker for peri-implantitis (24). The findings of this research suggest that CXCL14, in combination with miR-4484, can differentiate peri-implantitis patients with 100% success.

Hani S Almoharib et al.'s systematic review and meta-analysis on the relationship between changes in matrix metalloproteinase-8 (MMP-8) levels in peri-implant crevicular fluids (PICF) and peri-implantitis (1). The diagnosis of peri-implantitis typically involves assessing inflammation, pocket depth, bleeding, and bone loss, but these methods mainly determine the history of the disease rather than its present activity or susceptibility. Therefore, the potential use of MMP-8 as a diagnostic marker for peri-implantitis is explored in this study. The research involved a comprehensive search for original cross-sectional and longitudinal studies comparing MMP-8 biomarkers in crevicular fluids around healthy implants with those around implants affected by peri-implantitis. The meta-analysis showed a significant increase in MMP-8 levels in individuals with peri-implantitis compared to those with healthy implants. The study concluded that MMP-8 levels in PICF were significantly elevated in peri-implantitis cases compared to healthy controls, indicating a potential link between MMP-8 and peri-implantitis. However, the meta-analysis did not provide evidence for MMP-8 as a diagnostic test for peri-implantitis. The paper provides a comprehensive overview of the potential role of MMP-8 in the inflammatory process and progression of peri-implantitis, highlighting the need for further research to establish its diagnostic value and understand the underlying mechanisms associated with peri-implantitis.

Other studies compared the immunological features of peri-implantitis (PI) and periodontitis using fluorescence-activated cell sorting (FACS) analysis with a wide panel of antibodies to identify and quantify immune cells in human PI and periodontitis lesions (25). The comparison showed similar immune cell compositions and ratios, with a higher proportion of T-cells in PI compared to periodontitis lesions. The study revealed similarities in the immune responses of both pathologies, suggesting similar immunological features, despite some subtle differences in the proportions of certain immune cell types. The authors highlighted the potential clinical relevance of flow cytometry analysis for identifying and quantifying immune cells in PI and periodontitis, including the sub-classification of T cells and the detection of immune cells requiring multiple markers for identification.

Non-surgical treatment

Periimplantitis treatment has been largely investigated, and one of the most proposed therapies is non-surgical. Ritu Saneja et al. systematic review and meta-analysis assessed the efficacy of laser therapy and photodynamic therapy (PDT) as adjunctive or primary therapies in the treatment of peri-implantitis and peri-implant mucositis (26). Peri-implant diseases result in pathological changes in the peri-implant tissues and loss of osseointegration, posing potential problems and complications for implants. The review included 11

randomized controlled clinical trials, comparing the effectiveness of various lasers and PDT to conventional procedures. Statistical analyses were conducted to assess mean difference and confidence intervals for probing depth (PD) and clinical attachment level (CAL). The literature search yielded 113 articles, with 11 included for quantitative analysis. The findings suggest that laser treatment as an adjunctive therapy or monotherapy in peri-implantitis does not show superior effects compared to conventional measures, as it came out from the 2017 Consensus report. However, laser therapy has shown more promising results in treating peri-implant mucositis compared to peri-implantitis.

Luigi Barbato et al. evaluated the clinical efficacy of different adjunctive methods/therapies to the non-surgical treatment of peri-implantitis (27). The review included 16 randomized clinical trials comparing non-surgical treatment alone versus non-surgical treatment plus any adjunctive method. The primary outcome was probing pocket depth (PPD) reduction. The outcomes revealed that non-surgical treatment with or without adjunctive methods may reduce PPD and bleeding on probing (BoP), but complete resolution of the pocket is unpredictable. The review highlighted that systemic antimicrobials were associated with higher PPD reduction and treatment success compared to non-surgical treatment alone. However, adjunctive local antimicrobials and lasers did not show significant differences in PPD and BoP reduction. The recurrence and progression rate of peri-implantitis was reported to be 44%, with 27% implant loss even after treatment. The most effective adjunctive method proposed for implant surface decontamination was systemic antibiotics, although caution should be exercised in their usage due to potential antibiotic resistance. The review concluded that non-surgical treatment with or without adjunctive methods may reduce PPD and BoP, but complete resolution of peri-implantitis is unpredictable. Systemic antibiotics may provide further benefits, but their usage should be considered cautiously.

Considering the contradictory findings of previous studies, the objective of the research paper by Siyan Liu et al. was to assess the efficacy of chlorhexidine (CHX) in enhancing outcomes for non-surgical management of peri-implant mucositis and peri-implantitis. The systematic review and meta-analysis included seven studies, four of which evaluated CHX in peri-implant mucositis and three in peri-implantitis. The findings indicated that the use of CHX did not significantly improve probing depths in peri-implant mucositis or peri-implantitis. Moreover, results on the effectiveness of CHX in reducing bleeding on probing (BOP) in peri-implantitis were conflicting. The included studies utilized different forms and concentrations of CHX, as well as variations in treatment protocols, which may have influenced the overall results. The paper also discussed the limitations of the review, including the small number of available studies, methodological heterogeneity, and variations in the treatment protocols. It emphasized the need for high-quality RCTs with homogeneous methodology to better understand the role of CHX as an adjunctive therapy for peri-implant mucositis and peri-implantitis. In conclusion, the meta-analysis results suggest that adjunctive therapy with CHX may not improve outcomes in the non-surgical management of peri-implant mucositis, and findings regarding its role in peri-implantitis cannot be drawn. The author stressed the importance of future research focusing on the use of CHX in peri-implant diseases and the need for more conclusive evidence.

Antibiotics

Antibiotics are frequently employed in conjunction with mechanical debridement to deal with the infectious component of peri-implantitis. The microbial etiology of peri-implantitis involves a complex interplay of various bacteria, including periodontal pathogens such as Porphyromonas gingivalis and Aggregatibacter actinomycetemcomitans. Several studies have investigated the use of systemic and local antibiotics to combat peri-implant infections. Systemic antibiotic therapy, such as amoxicillin and metronidazole, has demonstrated efficacy in reducing inflammation and controlling bacterial load in peri-implantitis cases. Local antibiotic

delivery systems, such as minocycline microspheres or doxycycline gel, have gained attention for their targeted approach in treating peri-implant infections (28). These localized treatments aim to achieve higher antibiotic concentrations at the implant site while minimizing systemic exposure. Despite the widespread use of antibiotics, controversies exist regarding the optimal dosage, duration, and choice of antibiotics for peri-implantitis treatment. Additionally, the emergence of antibiotic-resistant strains raises questions about the long-term effectiveness of antibiotic therapy in this context.

Maria Gabriella Grusovin et al. investigated the efficacy of using antibiotics, both locally and systemic, as an adjunctive non-surgical therapy for peri-implantitis, based on the 2017 World Workshop on Periodontal Diseases' definition of the condition (29). Six randomized controlled trials were included in the review, consisting of two studies using topical and four using systemic antibiotics. The findings indicated that adjunctive local antibiotics showed improved outcomes in terms of success rate, probing pocket depth (PPD), and bleeding on probing (BOP), while adjunctive systemic antibiotics improved PPD and probing attachment level (PAL) only. Specifically, adjunctive local antibiotics demonstrated significant improvements in PPD and BOP, leading to a success rate of 20-30%, while adjunctive systemic antibiotics led to PPD and PAL improvements, with a success rate of 2-65%. However, the findings were based on a limited number of studies, showing high heterogeneity and potential bias, thus leading to controversial results. The author emphasized the need for well-designed randomized controlled clinical trials to accurately assess the efficacy of antibiotics in peri-implantitis treatment, considering the risks of antibiotic resistance and the lack of consensus in treatment protocols.

Manuel Toledano et al. 2021 analyzed the efficacy of local antibiotic therapy in treating peri-implantitis, focusing on the reduction in peri-implant probing depth (PPD) and bleeding on probing (BoP) (30). The study involved a systematic review and meta-analysis of twelve studies with a total of 365 patients and 463 implants. The findings indicate that local administration of antibiotics led to a reduction of 1.40 mm in PPD and a 0.30 mm higher reduction in PPD compared to the control group. Additionally, the odds of BoP were 1.82 times higher when antibiotics were not locally administered. No adverse effects were found after applying local antibiotics. The research also discusses different antibiotics and their effectiveness in managing peri-implantitis. It highlights that while local application of antibiotics showed positive results, systemic antibiotics can have undesirable side effects such as dysbiosis and antibiotic resistance. The paper emphasizes the need for further clinical trials with longer follow-up periods and larger sample sizes to validate the findings and determine the sustained effects of local antibiotic administration in treating peri-implantitis. Overall, the study concludes that local antibiotic administration reduces PPD and BoP in patients with peri-implantitis without adverse effects, suggesting its efficacy in managing the condition.

In the 2022 systematic review and meta-analysis, Toledano et al. focused on the efficacy of systemic antibiotic administration in treating peri-implantitis in terms of bleeding on probing (BoP) and probing pocket depth (PPD). Despite the common use of systemic antibiotics in peri-implantitis treatment, the findings suggested that the administration of systemic antibiotics in peri-implantitis did not significantly affect BoP or PPD. The study included 18 articles, 9 of which were randomized clinical trials, and involved 605 patients and 870 implants. The results indicated that systemic antibiotic administration did not lead to any significant reduction in BoP or PPD. Various antibiotics were examined, including metronidazole, amoxicillin, azithromycin, clindamycin, and tetracycline, but none demonstrated significant efficacy in reducing BoP or PPD. Furthermore, the duration of antibiotic administration and the follow-up time did not lead to significant differences in BoP or PPD reduction. Overall, the findings suggest that the existing scientific evidence does not support the significant efficacy of systemic antibiotics in reducing BoP or PPD in peri-implantitis treatment and emphasizes the need to address the problem of antibiotic resistance.

Nansi Lopez-Valverde et al. analyzed 38, 5 of which were selected for qualitative analysis. The studies dealt with the use of metronidazole as an add-on treatment (31). The results showed confirmation of the effectiveness of using metronidazole as an additional treatment in some studies, while other studies did not show significant benefits. The results indicate that the decision to use an additional antibiotic should be made based on the condition of each patient, taking into account the severity of the disease and its consequences, and caution should be taken against possible resistance to the selected antibiotic. In conclusion, the researchers argue that long-term clinical studies using standardized methodologies are necessary to determine the role of metronidazole as an add-on treatment for dental implant infections.

María Baus-Domínguez et al. focused their research on the use of antibiotics in the surgical treatment of peri-implantitis (32). The review included 14 articles comprehending a variety of randomized controlled trials and observational studies and, similarly to the previous revisions, investigates the role and efficacy of systemic and local antibiotics in improving therapeutic outcomes for peri-implantitis, specifically in terms of probing pocket depth (PPD) and bleeding on probing (BoP). The findings indicate that the adjunctive use of local antibiotics significantly improves PPD and BoP compared to surgical treatment alone. However, the use of systemic antibiotics did not show significant improvement in PPD changes. They reported a significant reduction in PPD and BoP with the use of local antibiotics, particularly minocycline and doxycycline, as adjuvant treatments in surgical therapy. However, they also emphasize the potential complications and risks associated with antibiotics, including resistance, alteration of microflora, and hypersensitivity, which need to be carefully evaluated.

Surgical therapy

The complex etiology of peri-implantitis involves microbial colonization on implant surfaces, triggering inflammatory responses and bone resorption. Surgical interventions have emerged as a key component in managing peri-implantitis, aiming to eliminate infection, resolve inflammation, and promote tissue regeneration by removing the infected tissues, debriding the implant surface, and promoting a favorable environment for tissue healing. One of the primary surgical approaches in peri-implantitis treatment is open-flap debridement. This procedure involves accessing the peri-implant tissues through a flap, allowing thorough debridement of the implant surface and removal of granulation tissue. Open-flap debridement is often combined with regenerative techniques, such as bone grafts or membranes, to enhance tissue regeneration and restore lost peri-implant support. While surgical interventions play a crucial role in managing peri-implantitis, challenges persist, including the risk of implant surface damage during debridement and the potential for disease recurrence. Additionally, patient-specific factors, such as implant design and bone quality, influence the choice and success of surgical approaches. Surgical treatment modalities for peri-implantitis are many and evolving, reflecting the ongoing efforts to refine and optimize therapeutic outcomes.

Karlsson et al. evaluated access flap and pocket elimination procedures in the surgical treatment of peri-implantitis (33). The review included studies comparing surgical therapy to non-surgical therapy and assessed reduction of probing depth (PD) and bleeding on probing (BOP) as primary outcome measures. Meta-analysis demonstrated significant reductions in PD (standardized mean effect: 2.2 mm) and BOP% (27.0) up to 5 years post-surgery. Marginal bone level gain was also observed. Disease recurrence was high over 5 years, and implant loss was not uncommon. The evidence suggests the effectiveness of access flap and pocket elimination surgery in managing peri-implantitis, but high rates of disease recurrence and implant loss were reported over 5 years. The study highlighted the influence of baseline conditions on treatment outcomes and emphasized the need for further evidence regarding clinical and patient-reported outcomes. The review also indicated the lack of studies directly comparing surgical with non-surgical therapy and the need for more robust evidence from

randomized controlled trials. The study concludes that surgical procedures are valid options for peri-implantitis treatment and may be considered by clinicians, but it emphasizes the need for more comprehensive evidence, particularly from randomized controlled trials, to further evaluate the efficacy and long-term outcomes of access flap and pocket elimination procedures.

The research of Baima et al. sought to address the efficacy of different implant surface decontamination protocols in the surgical treatment of peri-implantitis (34). The study included 22 manuscripts reporting 16 randomized clinical trials (RCTs) that tested mechanical, chemical, and physical decontamination protocols. The findings suggested that all decontamination protocols resulted in improved clinical parameters, but no single method demonstrated clear evidence of superiority over others. However, titanium brushes and implantoplasty showed favorable results as single decontamination methods. Meta-analyses indicated that Er: Yag laser did not have a significant added effect on probing pocket depth (PPD) reduction, while systemic antimicrobials (amoxicillin or azithromycin) showed an added impact on treatment success but not in terms of PPD reduction. The study emphasized the lack of consistent evidence regarding the superiority of any decontamination protocol. It highlighted the need for well-designed RCTs to identify the most effective decontamination method for peri-implantitis treatment. The authors also noted limitations in the available trials, such as the reliance on single RCTs and the high heterogeneity among the included trials.

Asaf Wilensky et al. examined the efficacy of surgical therapy with chemical surface decontamination of implant surfaces compared to surgical therapy alone or surgery with placebo decontamination for treating peri-implantitis (35). They included six RCTs assessing the adjunctive effect of photodynamic therapy (PDT), chlorhexidine (CHX), and local antibiotics (LAbs) during surgery on clinical outcomes. The results showed that adjunctive use of local antibiotics resulted in clinically relevant reduction of pocket depth (PD) and radiographic marginal bone loss (MBL) at 12 months. PDT showed a small but significant reduction in bleeding on probing (BoP). Treatment with CHX resulted in no significant changes in PD, BoP, or MBL compared to placebo (saline solution). However, the authors found no decisive evidence showing that the adjunctive use of chemical implant surface decontamination improves the outcome of surgical therapy for peri-implantitis; in other words, for the authors, chemical decontamination of implant surfaces, in addition to surgical debridement, does not provide any additional benefit based on the current evidence. The limitations of the review include the paucity of evidence and small sample sizes in some studies, as well as variability in the definition of peri-implantitis, variability in inclusion criteria between studies, and heterogeneity in surgical techniques and outcome measurements.

At least Jing Cheng et al. investigated the effectiveness of various surgical methods for treating peri-implantitis. A total of 13 articles were included in the study, involving open flap debridement (OFD), resective therapy (RT), and augmentative therapy (AT) with and without adjunctive treatments (36). The study found that augmentative therapy improved radiographic bone fill (RBF) and clinical attachment level (CAL) more than OFD but did not outperform OFD in reducing soft-tissue inflammation. Additionally, adjunctive treatments, such as ozone therapy, improved the effectiveness of AT, but the evidence supporting this combination therapy is limited. The authors suggest that within the limitations of the study, AT was superior to OFD in improving peri-implantitis outcomes, as reported by others (37). The paper also discusses the prevalence of peri-implantitis, treatment options, the lack of reliable evidence for the most effective interventions, the rigorous methods used in the systematic review, and the assessment of the risk of bias and overall quality of evidence. The study concluded that future research should involve well-designed, high-quality, randomized controlled trials with larger sample sizes to address certain limitations in the findings.

CONCLUSIONS

The management of peri-implantitis encompasses various aspects, from understanding its prevalence and correlations to identifying relevant markers and exploring both non-surgical and surgical treatment modalities. This comprehensive review aimed to provide insights into the current state of knowledge in the field.

The prevalence of peri-implantitis remains challenging to assess due to inconsistent reporting in studies. The multifactorial nature of this condition contributes to prevalence variations, emphasizing the need for standardized diagnostic criteria. Consensus on disease classification and consistent periodontal measurements is crucial for accurate epidemiological assessments.

Correlations between peri-implantitis and various factors, including viral presence (Epstein–Barr virus) and bacterial composition, have been explored. While associations with the Epstein–Barr virus were inconclusive, specific bacteria like S. epidermidis and periodontopathogens showed strong links. Additionally, studies examining the impact of glycemic levels on peri-implantitis revealed worse outcomes in diabetic patients, emphasizing the need for personalized treatment approaches. Efforts to identify molecular markers for peri-implantitis have focused on salivary biomarkers, miR-4484, and matrix metalloproteinase-8 (MMP-8). The combination of CXCL14 and miR-4484 showed promise in differentiating peri-implantitis patients. MMP-8 levels in peri-implant crevicular fluids were elevated in peri-implantitis cases, suggesting a potential link. However, more research is needed to establish their diagnostic value.

Non-surgical therapies, including laser and photodynamic therapy, were assessed in managing peri-implantitis. While laser therapy did not show superiority over conventional measures, systemic antimicrobials, especially antibiotics, were associated with a higher reduction in probing pocket depth. Chlorhexidine's efficacy was inconclusive, highlighting the need for standardized protocols and long-term studies. Furthermore, antibiotics play a significant role in peri-implantitis treatment, with studies investigating both systemic and local administration. Local antibiotics, particularly minocycline and doxycycline, showed improvements in probing pocket depth and bleeding on probing. Despite common usage, systemic antibiotics did not significantly affect bleeding on probing or pocket depth, raising concerns about antibiotic resistance.

Surgical treatments are crucial in peri-implantitis management. Access flap and pocket elimination procedures demonstrated significant reductions in probing depth and bleeding on probing. Implant surface decontamination protocols, including mechanical, chemical, and physical methods, showed varied effectiveness. Chemical surface decontamination with photodynamic therapy, chlorhexidine, and local antibiotics demonstrated mixed results, emphasizing the need for more robust evidence. Augmentative therapy, especially with adjunctive treatments, showed promise in improving radiographic bone fill and clinical attachment level compared to open-flap debridement.

Cases subjected to radiotherapy or antiresorptive and antiangiogenic drugs would deserve a more in-depth discussion that goes beyond this review, where peri-implantitis can transform into dramatic cases requiring extensive demolitions and complex reconstructions (38).

In conclusion, the complex nature of peri-implantitis demands a multidimensional approach. As highlighted in other districts, the sharing of the skills of different specialists guarantees a complete evaluation of patients, with an improvement not only in treatment but also in quality of life (39). Standardized diagnostic criteria, personalized treatment strategies, and ongoing research are crucial for advancing our understanding and improving outcomes in peri-implantitis management. Further well-designed randomized controlled trials and longitudinal studies are essential to validate findings and establish evidence-based guidelines for optimal patient care.

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