Editors: N. Donos, S. Barter, D. Wismeijer

ITI

International Team for Implantology

ITI Treatment Guide

Volume 13

Prevention and Management of Peri-Implant Diseases

Authors:
L. J. A. Heitz-Mayfield
G. E. Salvi

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The ITI Mission is ...

"... to serve the dental profession by providing a growing global network for life-long learning in implant dentistry through comprehensive quality education and innovative research to the benefit of the patient."

Preface

For many years now, the use of dental implants in everyday clinical practice has been established as one of the most predictable treatment options for the successful restoration of missing teeth.

There is, however, an increasing body of knowledge in the literature showing that biologic complications around implants, including peri-implant diseases, are a clinical reality that is often difficult to address.

The definition and criteria of peri-implant diseases have not always been universally accepted. Recently, the World Workshop in Periodontology 2017 provided clarification and diagnostic criteria for healthy conditions around implants, as well as defining peri-implant diseases. Definitive solutions and treatments remain unclear, with numerous modalities and factors affecting the predictable treatment of peri-implantitis remaining under investigation.

In this volume, all the aspects from the etiology of peri-implant diseases to their treatment are thoroughly discussed over twelve chapters, including seventeen clinical cases. This volume provides invaluable recommendations and clinical guidelines for which the ITI is renowned, that will help clinicians to provide the proper diagnosis and treatment when they face such challenging clinical situations.

N. Donos S. Barter D. Wismeijer

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Table of Contents

1 Introduction

L. J. A. Heitz-Mayfield, G. E. Salvi

The use of osseointegrated implants has become a routine procedure in clinical practice for the replacement of missing teeth with removable or fixed dental prostheses. Outcomes from long-term studies indicate that implant-supported restorations are a predictable treatment method for the management of fully and partially edentulous patients (Buser and coworkers 2012; Wittneben and coworkers 2014; Derks and coworkers 2016a; Morton and coworkers 2018; Pjetursson and coworkers 2018; Sailer and coworkers 2018). However, interventions involving procedures for the surgical placement and restoration of implants are associated with risks of complications.

The process of osseointegration may be jeopardized by several factors, such as surgical trauma during preparation of implant recipient sites and premature loading. As a consequence, tissue necrosis may result during the early phases of healing, and patients may experience so-called "early" complications over a period of three to six months following implant placement. These complications are rare, but they may lead to implant loss.

Once osseointegration and the healing of the soft tissues are established, so-called "late" complications may also occur when implants are restored and in function. The most frequent biological complications are biofilm-initiated peri-implant diseases (peri-implant mucositis and peri-implantitis). Less common complications include medication-related complications, peri-implant mucosal disorders, peri-implant oncological disorders, material allergies, or complete loss of osseointegration and implant failure. Technical or mechanical complications related to the components and materials of the implant-supported prosthesis are more frequent than biological complications and can themselves lead to biological complications.

Before undertaking implant therapy, patients and clinicians need to carefully weigh the risks for the occurrence of mechanical/technical complications (Salvi and Brägger 2009; Heitz-Mayfield and Brägger 2015) and biological complications (Heitz-Mayfield and coworkers 2018a).

Prior to the commencement of implant therapy, patients should be informed by dental professionals that complications may occur, relating to the surrounding hard and soft tissues of the implant (biological complications) and to the implant-supported prosthesis (Abrahamsson and coworkers 2017). In addition, clinicians should be properly trained to prevent surgical and prosthetic complications and should be able to diagnose and manage them correctly. While patients must be properly informed and instructed on how to prevent complications, clinicians must understand the causes of such complications in order to make the correct diagnosis and implement the appropriate treatment.

Volume 13 of the ITI Treatment Guide series aims to provide a comprehensive overview on implant supportive care and peri-implant diseases (peri-implant mucositis/peri-implantitis) including their classification, etiology, prevalence, risk factors, prevention, diagnosis, and management.

The theoretical chapters of this ITI Treatment Guide are complemented by clinical case presentations illustrating various biological complications and their step-by-step management.

2 Classification and Definitions of Peri-Implant Health and Diseases

L. J. A. Heitz-Mayfield, G. E. Salvi

Following the completion of osseointegration and soft-tissue healing after implant placement, peri-implant diseases may develop if a biofilm is allowed to accumulate (Salvi and Ramseier 2015). This is in accordance with the observation that peri-implant diseases are initiated by the presence of similar etiological factors to those involved in the development of periodontal diseases (Heitz-Mayfield and Lang 2010).

In 2017, at the World Workshop on Classification of Periodontal and Peri-Implant Diseases and Conditions, new disease definitions and case definitions were presented for peri-implant health, peri-implant mucositis, and peri-implantitis (Berglundh and coworkers 2018a). This was the first time that implant conditions were addressed as part of the World Workshop Classification, the previous World Workshop having been held in 1999.

2.1 Definition of Peri-Implant Health

Healthy soft tissues surrounding an implant are termed peri-implant mucosa. Peri-implant mucosa is composed of a layer of connective tissue covered by either a keratinized or non-keratinized epithelium.

In health, small clusters of inflammatory cells can be found in the connective tissue lateral to the barrier epithelium. The peri-implant mucosa averages around 3 – 4 mm in height and the epithelium, which is approximately 2 mm long, faces the implant surface. However, the dimensions of the peri-implant mucosa, both in height and thickness, vary depending on factors including the depth of implant placement and the soft-tissue phenotype. Most of the endosseous part of the implant (about 60%) is in contact with mineralized bone, while the remaining part is in contact with bone marrow, vascular structures, and fibrous tissue. Clinically, peri-implant health is characterized by the absence of erythema, bleeding on probing, swelling, and suppuration (Araújo and Lindhe 2018) (Figs 1a-b).

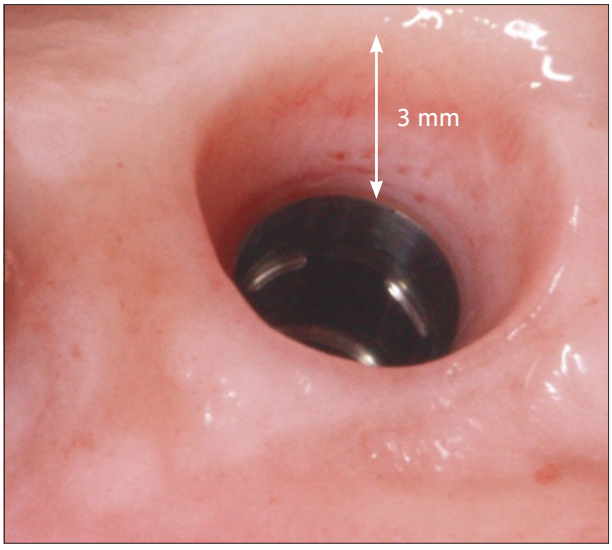


Fig 1a Healthy peri-implant mucosa surrounding a bone-level implant. Following the removal of a titanium healing abutment, the healthy peri-implant mucosa is observed with a dimension of approximately 3 mm of tissue height. Erythema and edema are absent.

Fig 1b Healthy peri-implant mucosa at implant site 11.

2.2 Definition of Peri-Implant Mucositis

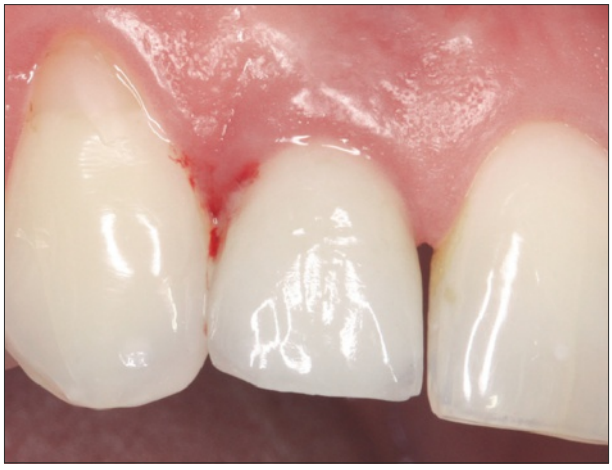


Fig 2 Peri-implant mucositis at implant site 12. Bleeding following gentle probing of the peri-implant sulcus.

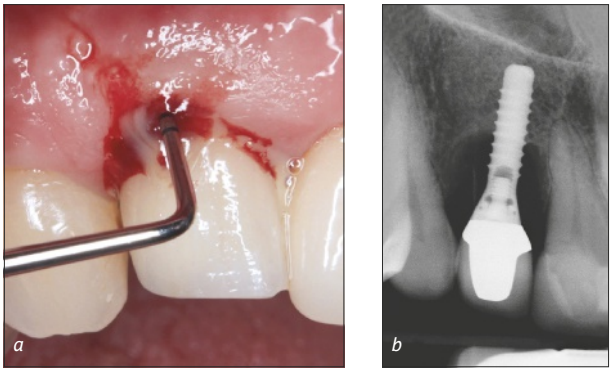
Peri-implant mucositis is defined as an inflammatory lesion in the soft tissues surrounding an implant in the absence of supporting bone loss or continuing marginal bone loss (Heitz-Mayfield and Salvi 2018). Peri-implant mucositis is caused by biofilms, which disrupt the host/parasite equilibrium at the implant-mucosa interface resulting in an inflammatory lesion in the supracrestal soft-tissue compartment (Heitz-Mayfield and Salvi 2018).

The main clinical characteristic of peri-implant mucositis is bleeding on gentle probing (Heitz-Mayfield and Salvi 2018) (Fig 2).

2.3 Definition of Peri-Implantitis

Peri-implantitis is defined as a biofilm-associated pathological condition occurring in the tissues around an osseointegrated implant, characterized by bleeding on probing (BoP) and/or suppuration and subsequent progressive loss of supporting bone (Schwarz and coworkers 2018) (Fig 3).

As with experimental periodontitis at teeth, the formation of a biofilm on the surface of an implant has been documented to be involved in the development of experimental peri-implantitis (Lindhe and coworkers 1992; Carcuac and coworkers 2013).



Figs 3a-b Peri-implantitis at implant site 12 (Straumann Soft Tissue Level narrow-diameter implant with a cemented crown). (a) Clinical signs of bleeding and suppuration on probing and (b) radiographic evidence of progressive loss of supporting bone with marginal bone levels at the level of thread 4 (bone level at approximately 50% of the implant length). The probing depth is > 6 mm.

3 Examination for Diagnosis and Case Definitions of Peri-Implant Diseases

L. J. A. Heitz-Mayfield, G. E. Salvi

In order to make appropriate treatment choices for the effective management of patients with peri-implant diseases, a correct diagnosis is required. In 2017, the World Workshop for the Classification of Periodontal and Peri-Implant diseases presented case definitions for peri-implant health, peri-implant mucositis, and peri-implantitis (Berglundh and coworkers 2018a). These case definitions have been proposed for universal reference to avoid the ongoing ambiguity and confusion that previously existed in this field.

In order to diagnose peri-implant diseases the clinician must assess both the peri-implant soft-tissue conditions (to detect signs of inflammation) and the peri-implant marginal bone levels. A correct diagnosis cannot be made from a radiograph alone. A clinical assessment of tissue conditions should always be made.

3.1 Assessment of Soft-Tissue Conditions

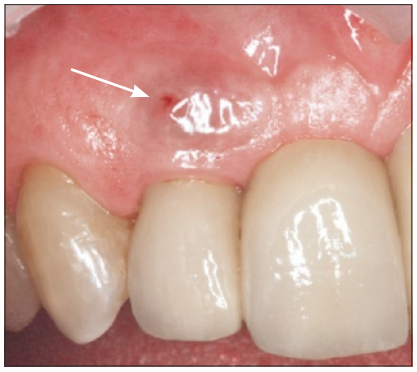


Fig 1 Peri-implant infection as seen by the presence of a draining sinus (white arrow) on the labial peri-implant mucosa of implant site 12. The draining sinus was detected by visual inspection.

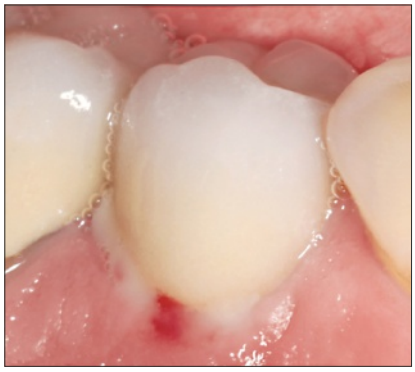
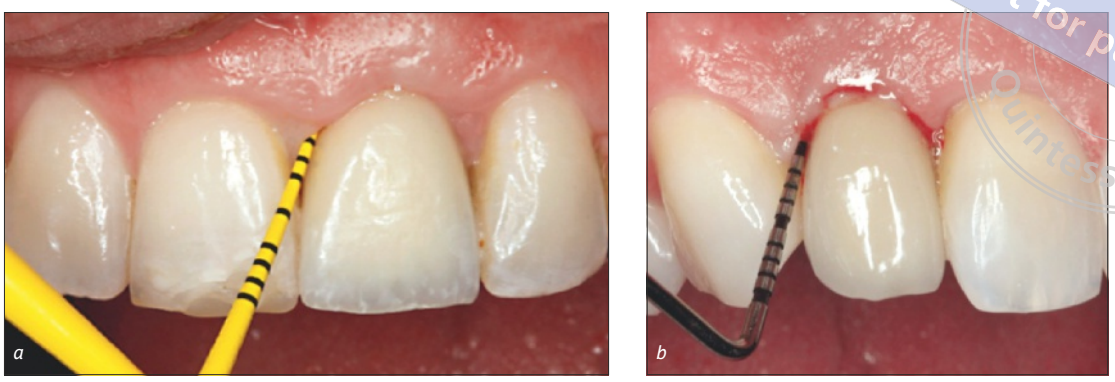


Fig 2 Suppuration and bleeding following digital palpation on the buccal aspect of implant site 45.

Detection of the presence of soft-tissue inflammation should include:

- Visual inspection to identify erythema, edema, or presence of a draining sinus (Fig 1)
- Digital palpation to detect presence of suppuration (Fig 2)
- Probing of the peri-implant sulcus to detect bleeding or suppuration on probing (Berglundh and coworkers 2018a) (Fig 3)

A metal or plastic periodontal probe can be used to perform peri-implant probing and a light probing force (approximately 0.25 Ncm) is recommended (Figs 3a-b). Peri-implant probing depths at four to six sites per implant should be assessed and recorded in order to identify changes in probing depths over time. It is recognized that there might be no access for probing of multiple sites per implant due to the position of the implant in relation to the prosthesis contours. Where access for probing at an implant is lacking, the prosthesis should be removed, if possible, in order to assess the peri-implant soft-tissue status (Serino and coworkers 2013).



Figs 3a-b Probing of the peri-implant sulcus to assess the peri-implant tissue status. A plastic (a) or metal (b) periodontal probe can be used with a light probing force (approximately 0.25 N).

Recording of the peri-implant mucosal margin in relation to a fixed reference point (such as the crown margin or incisal edge) is also valuable for detecting migration of the peri-implant mucosal margin over time. Clinical photographs are also useful for assessing changes in peri-implant mucosal levels over time.

3.2 Assessment of Marginal Bone Levels

When signs of inflammation are observed during a clinical examination, an intraoral radiograph (periapical or bitewing) should be made in order to assess the peri-implant marginal bone levels. The use of a paralleling device is recommended to allow correct positioning of the radiographic film or sensor and align the radiographic tube. A well-aligned radiograph allows measurements to be made from a fixed reference point, such as the most coronal aspect of the endosseous portion of the implant, to the first bone to implant contact (Fig 4). The clinician should be aware that panoramic radiographs are not recommended for assessment of peri-implant marginal bone levels due to an unfavorable projection geometry leading to magnification errors and superimposed structures.

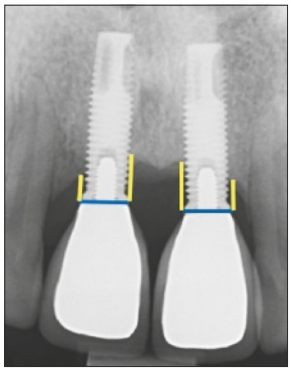


Fig 4 Periapical radiograph of two adjacent bone level implants. A fixed reference point such as the most coronal aspect of the endosseous portion (blue line) is identified and measurements can be made to the marginal bone (yellow lines).

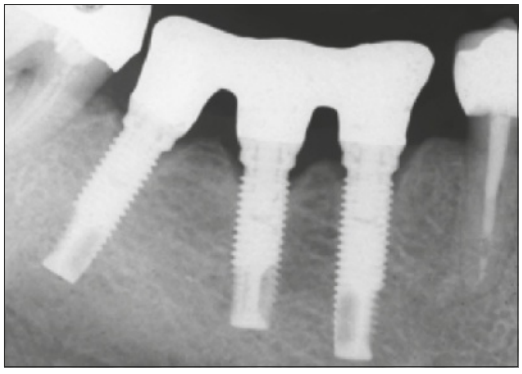


Fig 5a Periapical radiograph showing marginal bone levels at the time of placement of the implant-supported prosthesis. Marginal bone levels are at or above the level of the first implant thread on all implants.

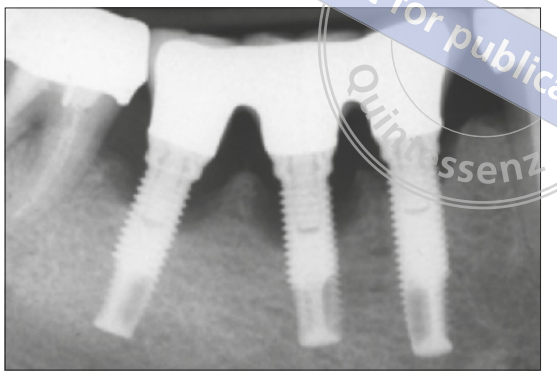


Fig 5b Periapical radiograph at five years following restoration of the implants showing progressive marginal bone loss at the three implants.

In order to determine if peri-implant bone loss has occurred, a comparison should be made between the peri-implant marginal bone levels from previous radiographs, preferably taken at the time of restoring the implant (Figs 5a-b). If not available, the clinician should make efforts to obtain previous radiographic records where possible.

When comparing marginal bone levels on radiographs, it must be recognized that there will be a measurement error of approximately 0.5 mm. Furthermore, if a series of radiographs have different angulations, the potential for measurement error increases (Walton and Layton 2018).

A radiograph is also useful for assessing the fit of the components of the implant-supported prosthesis (Fig 6), or identifying presence of submucosal luting cement remnants if a radiopaque cement has been used (Fig 7).

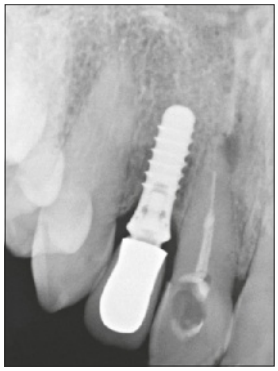


Fig 6 Radiograph showing an incompletely seated cement-retained implant crown.

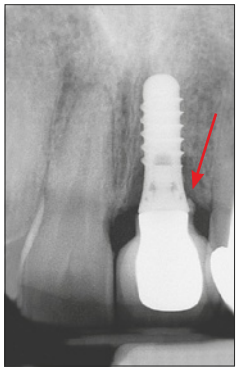


Fig 7 Radiograph showing a cement-retained implant crown and radiographic presence of excess luting cement, depicted by the red arrow.

3.3 Case Definitions

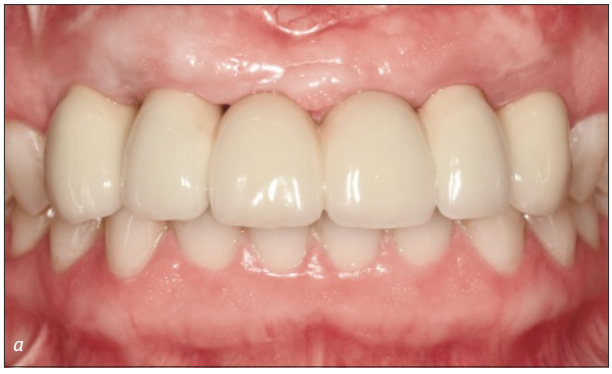
Based on the outlined clinical and radiographic diagnostic criteria, the following case definitions were agreed upon at the 2017 World Workshop on Periodontal and Peri-Implant Diseases (Berglundh and coworkers 2018a). These case definitions can be used in clinical practice as well as for epidemiological studies.

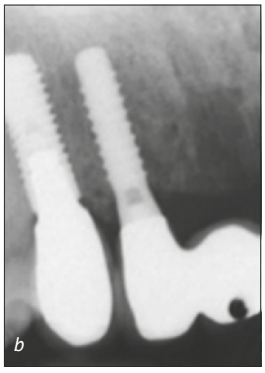
3.3.1 Case Definition of Peri-Implant Health

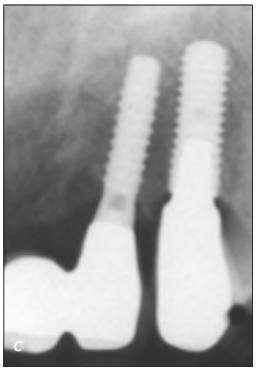
The following requirements should be fulfilled in a case of peri-implant health (Berglundh and coworkers 2018a) (Fig 8).

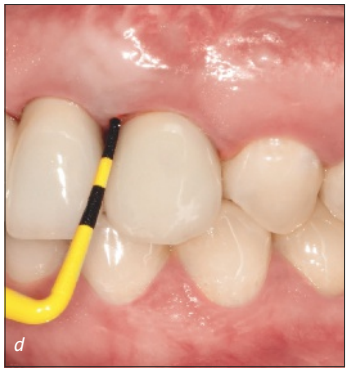
- Absence of clinical signs of inflammation
- Absence of bleeding and/or suppuration on gentle probing
- No increase in probing depth compared to previous examinations
- Absence of bone loss beyond crestal bone level changes resulting from initial bone remodeling

Probing depth measurements will depend on the height of the mucosal sulcus at the location of the implant. A range of probing depths may be compatible with peri-implant health, depending on the depth of implant placement and thickness of the soft tissue. It is the absence of clinical signs of inflammation (BoP) rather than the probing depth per se that indicates peri-implant health. Peri-implant tissue health may also be present around implants with variable levels of bone support.

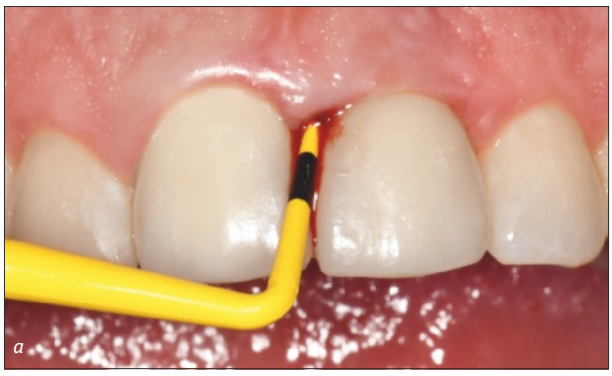


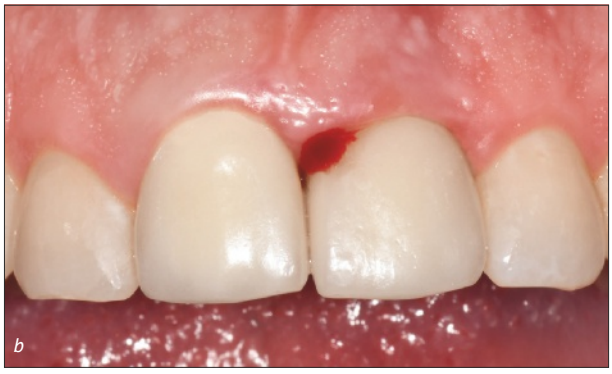


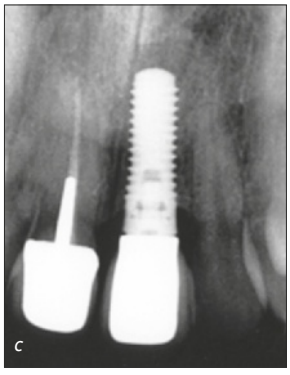




Figs 8a-d Peri-implant health. Clinical and radiographic images of implant-supported restorations surrounded by healthy peri-implant tissues. Absence of bleeding on probing (BoP), erythema, or swelling are observed.







Figs 9a-c Peri-implant mucositis. Clinical and radiographic images of an implant-supported single crown at site 21 diagnosed with peri-implant mucositis. The presence of bleeding on probing can be observed. The radiograph shows an ill-fitting crown margin as demonstrated by a submucosal gap between the crown and the implant shoulder. There is no loss of supporting peri-implant bone seen on the radiograph.

3.3.2 Case Definition of Peri-Implant Mucositis

The following requirements should be fulfilled in a case of peri-implant mucositis (Berglundh and coworkers 2018a) (Fig 9).

- Presence of bleeding and/or suppuration on gentle probing with or without increased probing depths compared to previous examinations
- Absence of bone loss beyond crestal bone level changes resulting from initial bone remodeling

Visual signs of inflammation can vary, and peri-implant mucositis can exist around implants with variable levels of bone support.

3.3.3 Case Definition of Peri-Implantitis

The following requirements should be fulfilled in a case of peri-implantitis (Berglundh and coworkers 2018a) (Fig 10).

- Presence of bleeding and/or suppuration on gentle probing
- Increased probing depth compared to previous examinations
- Presence of bone loss beyond marginal bone level changes resulting from initial bone remodeling, such as evidence of progressive bone loss

If data from previous examinations are lacking, a diagnosis of peri-implantitis can be based on the combination of:

- Presence of bleeding and/or suppuration on gentle probing
- Probing depths ≥ 6 mm
- Bone levels ≥ 3 mm apical of the most coronal portion of the endosseous part of the implant

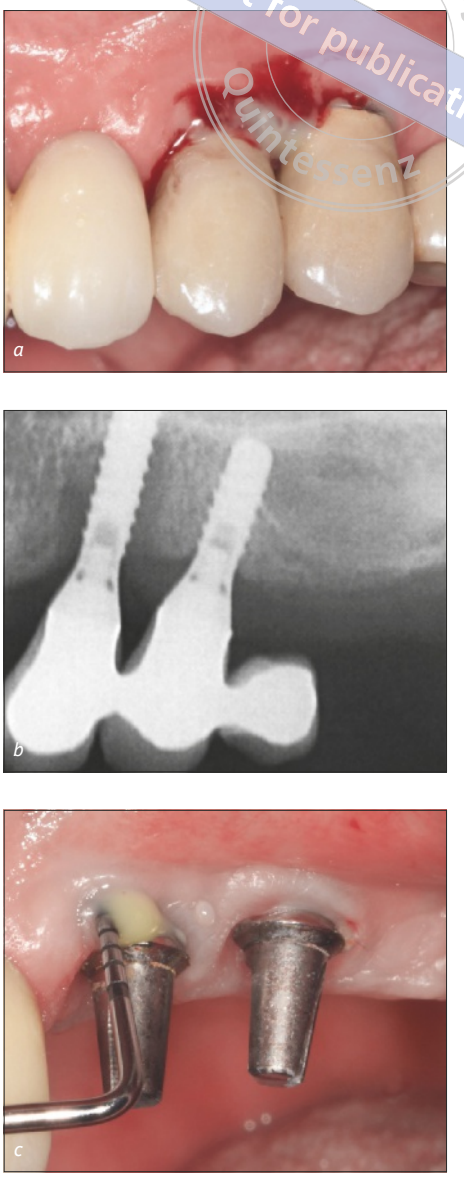


Fig 10a-c Peri-implantitis. Clinical and radiographic illustrations of an implant-supported fixed dental prosthesis with a distal cantilever extension. Presence of both bleeding on probing and suppuration combined with deep (PD > 6 mm) peri-implant probing depths and severe marginal bone loss around the mesial implant can be observed.

4 Etiology of Peri-Implant Diseases

L. J. A. Heitz-Mayfield, G. E. Salvi

4.1 Microbial Etiology of Peri-Implant Diseases

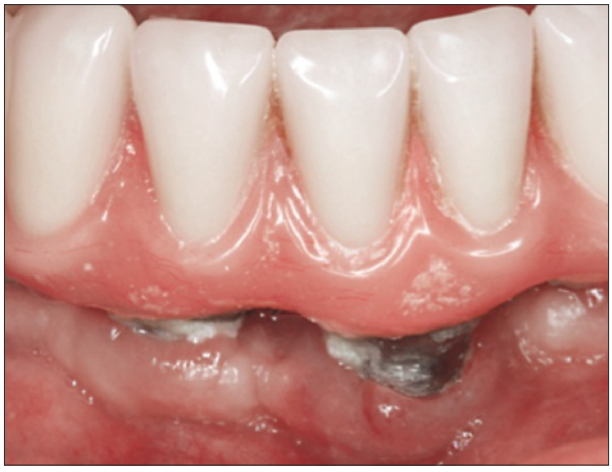


Fig 1 Peri-implant biofilm accumulation at implants in an edentulous patient with an implant-supported prosthesis.

Peri-implant mucositis and peri-implantitis have been defined as biofilm-induced inflammatory conditions (Berglundh and coworkers 2018a). There is substantial evidence for the microbial etiology of peri-implant diseases as outlined in this chapter. In summary, evidence for the microbial etiology of these diseases is highlighted in:

- Experimental animal studies showing a cause-and-effect relationship (Lindhe and coworkers 1992; Schou and coworkers 1993; Lang and coworkers 1993)
- Experimental human studies demonstrating a cause-and-effect relationship (Pontoriero and coworkers 1994; Salvi and coworkers 2012; Meyer and coworkers 2017; Zitzmann and coworkers 2001)
- Observational clinical studies showing association (Koyanagi and coworkers 2010; Kumar and coworkers 2012; Tamura and coworkers 2013; Apatzidou and coworkers 2017; Sanz-Martín and coworkers 2017; Al-Ahmad and coworkers 2018)
- Interventional clinical studies showing resolution of disease and prevention of progression of disease following anti-infective measures (Heitz-Mayfield and coworkers 2012; Heitz-Mayfield and coworkers 2018b; Carcuac and coworkers 2017; Berglundh and coworkers 2018b)
- While there is no unique microorganism associated with peri-implant mucositis or peri-implantitis, the accumulation of biofilms is considered the main etiologic agent in the initiation and progression of the disease process (Fig 1)

This chapter describes the peri-implant microbial profiles associated with peri-implant health and disease. In addition, the accompanying computer-animated 3D film (*Peri-Implantitis and its Prevention*; Quintessence Publishing 2018) illustrates the formation of peri-implant biofilms in health and disease. To view this film in full and for free, you need to be an ITI Member and logged in at www.iti.org.

Computer-animated 3D film
Peri-Implantitis and its Prevention.

4.1.1 Microbial Profiles at Healthy Implant Sites

Peri-implant microbiomes have been studied using various microbiological identification techniques including culture analysis, microscopy, DNA probe analysis, and molecular techniques such as 16S pyrosequencing and Illumina sequencing. As molecular techniques become more sophisticated, our understanding of the diversity and role of the peri-implant microbiome continues to expand.

Microbiota associated with healthy peri-implant conditions have been evaluated in cross-sectional studies, characterizing their composition as being predominately composed of gram-positive facultative cocci and rods, but also containing small numbers and low proportions of gram-negative anaerobic rods (Leonhardt and coworkers 1999; De Boever and De Boever 2006; Fürst and coworkers 2007).

Moreover, in partially edentulous patients treated for periodontitis and enrolled in supportive care, biofilm formation on newly placed implants occurs rapidly, and the remaining dentition acts as a reservoir for bacterial colonization of implant sites (Leonhardt and coworkers 1999; Mombelli and coworkers 1995; van Winkelhoff and coworkers 2000; De Boever and De Boever 2006; Quirynen and coworkers 2006; Fürst and coworkers 2007; Salvi and coworkers 2008).

Fürst and coworkers (2007) assessed the pattern of bacterial colonization at implants in periodontally treated patients with good levels of plaque control for up to three months following implant placement. Biofilm samples were collected from the sulci of transmucosal healing abutments from 14 subjects. A total of 40 bacterial species were analyzed by means of DNA-DNA checkerboard hybridization and compared with bacteria colonizing adjacent tooth sites. Biofilm formation occurred within 30 minutes after implant placement. Between 30 minutes and seven days, only one bacterial species, *Veillonella parvula*, yielded higher bacterial loads at implant sites compared with adjacent tooth sites. At three months, the composition of bacterial species was similar at implant and tooth sites; however, the bacterial load was higher at tooth sites compared with implant sites (Fürst and coworkers 2007).

Additional studies employing molecular detection methods found that titanium and zirconia abutment surfaces are rapidly colonized by a bacterial community similar to that found at adjacent teeth (de Freitas and coworkers 2018; Raffaini and coworkers 2018).

4.1.2 Microbial Profiles at Diseased Implant Sites

Overwhelming evidence indicates that, similar to periodontal diseases, peri-implant diseases are associated with bacterial biofilms predominately composed of gram-negative anaerobic taxa (Koyanagi and coworkers 2010; Kumar and coworkers 2012; Tamura and coworkers 2013; Apatzidou and coworkers 2017; Sanz-Martín and coworkers 2017; Al-Ahmad and coworkers 2018). Furthermore, the severity of peri-implantitis has been shown to be correlated with substantial changes in the submucosal microbiome, with increasing levels of dysbiosis as severity increases (Kröger and coworkers 2018). Dysbiosis is a term used to characterize microbial shifts with bacterial taxa normally associated with health becoming under-represented and outcompeted by bacterial taxa associated with disease. Microbial shifts in the oral cavity may result from an imbalance between the bacterial challenge and the inflammatory response in a susceptible host.

In contrast to biofilms detected at healthy peri-implant sites, the microbiome at sites characterized with peri-implant disease has been described as similar to that associated with periodontitis (Mombelli and Decaillet 2011; Charalampakis and coworkers 2012).

However, in a study using 16S pyrosequencing it was reported that the peri-implant microbiome differed significantly from that found at tooth sites, both in health and disease (Kumar and coworkers 2012). In that study, peri-implantitis was characterized as a microbially heterogeneous infection with less complexity compared to that of periodontitis (Kumar and coworkers 2012).

Using DNA-DNA checkerboard analysis, Persson and Renvert (2014) investigated the presence of 78 bacterial species in the biofilm at 166 implants diagnosed with peri-implantitis and 47 with peri-implant health. Of the 78 bacterial species, 19 were found at higher counts at implants with peri-implantitis compared with healthy implants. In that study, a cluster of bacteria including *P. gingivalis, Staphylococcus aureus, S. anaerobius, S. intermedius, S. mitis, T. forsythia*, and *T. socranskii* were found to be associated with peri-implantitis (Persson and Renvert 2014).

An additional comparison of the microbial biofilm in both periodontal and peri-implant health and disease was reported by Zhuang and coworkers (2016). In that study, bacterial samples of 22 patients with healthy and diseased implant sites as well as with healthy and diseased periodontal sites were analyzed in order to quantify the presence of 6 pathogens (Zhou and coworkers 2016; Zhuang and coworkers 2016). Although within the same patient, detection frequencies were higher at diseased tooth and implant sites compared with healthy sites, putative pathogens were detected at all sites irrespective of health status (Zhuang and coworkers 2016). In that patient sample, *P. gingivalis* and *Fusobacterium nucleatum* were not associated with peri-implantitis (Zhuang and coworkers 2016).

Using Illumina sequencing, Sanz-Martín and coworkers (2017) investigated microbial differences at sites characterized by peri-implant health or peri-implantitis. Overall, diseased peri-implant sites presented a higher diversity compared with that observed at healthy sites. More specifically, diseased peri-implant sites were primarily colonized by *Bacteroides, Spirochetes* and *Synergistetes*, whereas healthy peri-implant sites mostly harbored *Proteobacteria* and *Actinobacteria* (Sanz-Martín and coworkers 2017). The relative abundance of the genera *Porphyromonas, Treponema, Filifactor, Fretibacterium, Synergistetes*, and *Tannerella* was significantly higher in peri-implantitis sites compared with healthy implant sites. On the other hand, bacteria such as *Streptococcus, Veillonella, Rothia,* and *Haemophilus* displayed a significantly higher relative abundance at healthy compared with peri-implantitis sites (Sanz-Martín and coworkers 2017).

Collectively, the outcomes of the studies presented above indicate that, depending on the diagnostic technique applied, significant differences in microbial load and diversity between teeth and implants both in health and disease may be observed. Studies evaluating patient-specific microbiomes, using molecular techniques, indicate that peri-implant microbiomes are both complex and diverse (Dabdoub and coworkers 2013; Zhuang and coworkers 2016; Yu and coworkers 2019; Heuer and coworkers 2012).

4.1.3 Microbial Profiles in Edentulous Patients with Dental Implants

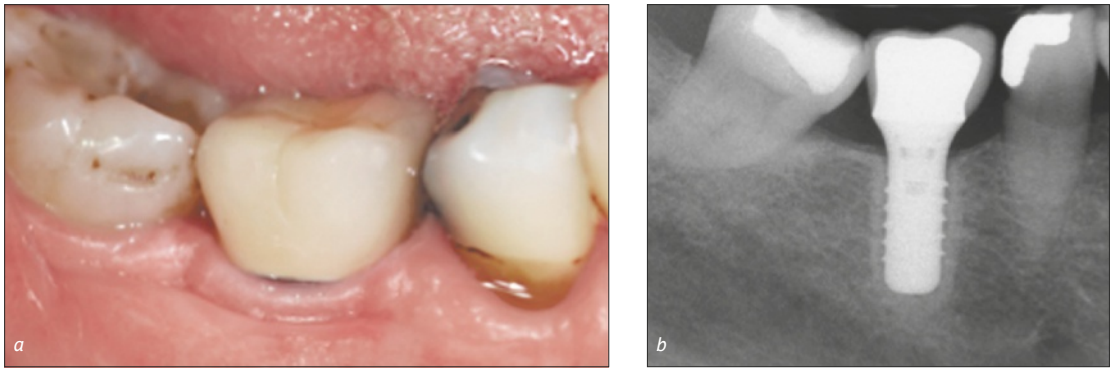
It was hypothesized that full-mouth tooth extraction may lead to the elimination of all hard and non-shedding surfaces, and subgingival habitats in the oral cavity, thereby favoring the disappearance of pathogenic bacteria (Danser and coworkers 1994; Danser and coworkers 1997).

In 1987, a first study using microscopic, immunochemical, and cultural methods challenged this hypothesis (Mombelli and coworkers 1987). The bacterial composition in 5 edentulous patients with healthy peri-implant conditions was compared with that in 7 edentulous patients presenting both healthy and diseased peri-implant conditions (Mombelli and coworkers 1987). Implants displaying signs of peri-implantitis harbored significantly elevated proportions of gram-negative bacteria, including black-pigmented *Bacteroides,* compared with non-diseased implants in both patient groups (Mombelli and coworkers 1987).

Later, quantitative polymerase chain reaction (qPCR) was used to monitor microbiological changes following full-mouth tooth extraction in 9 patients (Van Assche and coworkers 2009). The results showed that, following a period of six months of edentulism, periodontal pathogens could still be detected at low concentrations in the saliva and on the tongue (Van Assche and coworkers 2009).

In a follow-up study, the levels of the microbiota were monitored following a period of edentulism and up to one year after abutment connection (Quirynen and Van Assche 2011). The outcomes of that study indicated that pristine submucosal habitats around implants were colonized within ten days, suggesting that bacteria associated with periodontitis and peri-implantitis remain in the oral cavity following full-mouth tooth extraction (Quirynen and Van Assche 2011).

4.2 Alternative Theories for the Cause of Peri-Implantitis



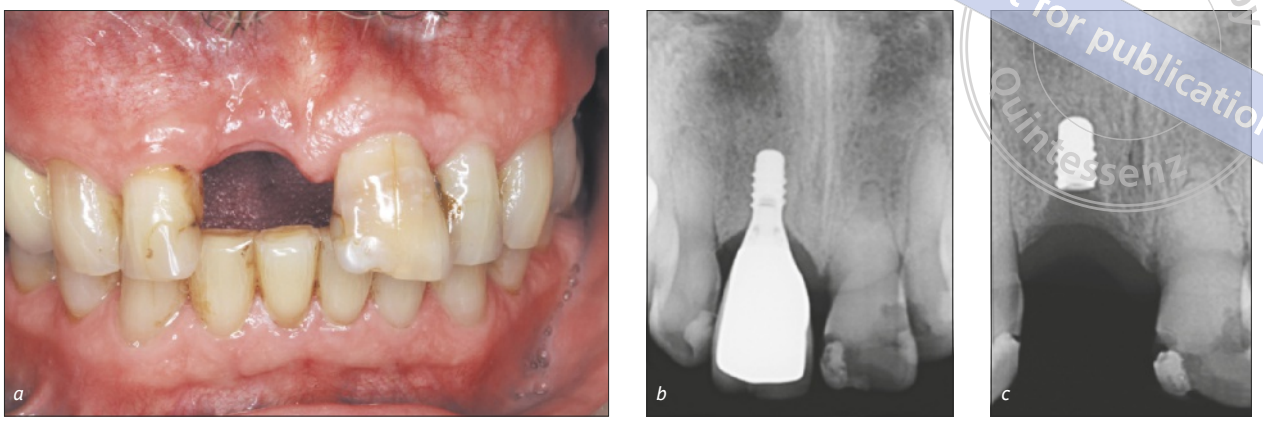
Figs 2a-b Implant site 46 has lost osseointegration after 18 years in function. This is not diagnosed as peri-implantitis, as there are no signs of marginal bone loss or clinical signs of inflammation (bleeding on probing and/or suppuration). The implant was mobile. There is a thin radiolucent line on the radiograph surrounding implant 46. While the etiology for the loss of osseointegration is unknown, excessive occlusal load is considered likely.

Alternative theories to explain the breakdown of peri-implant tissues and the loss of osseointegration have been proposed. Theories include excessive occlusal load (Gotfredsen and coworkers 2001; Heitz-Mayfield and coworkers 2004; Kozlovsky and coworkers 2007; Lima and coworkers 2019), foreign-body reaction theory (Albrektsson and coworkers 2019), and the presence of titanium particles (Fretwurst and coworkers 2016; Mombelli and coworkers 2018). Experimental peri-implantitis models incorporating these factors have either not been established or have not demonstrated the etiologic contribution of these factors to peri-implantitis.

While titanium particles and degradation products of titanium have been detected in oral tissues of patients with peri-implant biological complications, there is insufficient evidence to show a cause-and-effect relationship between biocorrosion, the presence of titanium particles, and peri-implant diseases (Mombelli and coworkers 2018).

4.2.1 Excessive Occlusal Load

The hypothesis that excessive load may constitute an etiologic or predisposing factor for peri-implantitis and progressive marginal bone loss still remains a matter of debate (Coli and coworkers 2017). While excessive load may result in mechanical and/or technical complications of the prosthesis or implant (Figs 2a-b), or in complete loss of osseointegration (Figs 3a-c), the evidence for excessive load and marginal bone loss is lacking. On the contrary, outcomes of preclinical experimental studies indicate that in the absence of peri-implant soft-issue inflammation, neither static nor dynamic excessive load result in the induction of peri-implant marginal bone loss (Gotfredsen and coworkers 2001; Heitz-Mayfield and coworkers 2004; Kozlovsky and coworkers 2007; Lima and coworkers 2019).



Figs 3a-c Fractured Implant site 11. A narrow-diameter TiZr tissue-level implant that fractured after ten years in function. No signs of clinical inflammation were observed. The patient had reduced posterior support and did not wear a nightguard, indicating that excessive occlusal load may have contributed to fracture of the implant. There was a high crown-to-implant ratio allowing for significant leverage on the mechanical components. (a) Clinical photograph of site 11 illustrating the implant fracture. No signs of clinical inflammation were present. (b) Radiographs showing the implant prior to fracture with no marginal bone loss and (c) following implant fracture.

Excessive load may be applied to an implant via the presence of premature occlusal contacts, oblique forces to the implant axis, bruxism, unfavorable crown-to-implant ratios, or cantilever extensions.

An experimental study in dogs compared the effects of excessive occlusal load on single titanium implants restored with a cantilever extension with non-loaded and normally loaded implants over a period of 6 months (Lima and coworkers 2019). The results indicated that excessive occlusal load applied to single implants with moderately rough surfaces and restored with a cantilever extension failed to induce loss of osseointegration or significant changes in clinical, radiographic, or histologic parameters (Lima and coworkers 2019). Excessively loaded implants, however, displayed a higher incidence of technical complications (Lima and coworkers 2019). A recent retrospective cohort study reported the outcomes of biological and technical complications of 21 patients with 25 single implants supporting single crowns with a cantilever extension (SCCs) with a follow-up of at least 10 years (Schmid and coworkers 2021). The results indicated that single implants supporting SCCs in posterior areas of the maxilla and mandible yielded a survival rate of 100% and were associated with minimal marginal bone level changes after a mean function time of 13.6 years (range: 10 – 19 years). The most frequent complication was loss of retention, noted on 3 occasions in 2 patients (Schmid and coworkers 2021).

Hence, these results are in accordance with those of previous studies failing to report a detrimental effect of cantilever extensions on peri-implant marginal bone levels (Wennström and coworkers 2004; Hälg and coworkers 2008; Romeo and coworkers 2009; Zurdo and coworkers 2009; Aglietta and coworkers 2012; de Freitas and coworkers 2018). Nevertheless, incidences of mechanical/technical complications were reported to be higher at implant-supported restorations with cantilever extensions when compared with those without extension (Kreissl and coworkers 2007; Salvi and Brägger 2009; Aglietta and coworkers 2009; Brägger and coworkers 2011).

5 Prevalence of Peri-Implant Diseases

L. J. A. Heitz-Mayfield, G. E. Salvi

Cross-sectional studies, while frequently cited, report widely diverging data for the prevalence of peri-implant diseases.

In 1994, the consensus report of group 4 of the 1st European Workshop on Periodontology (EWP) defined peri-implantitis as an inflammatory process around osseointegrated implants characterized by bleeding on probing and/or suppuration, pocket formation, and bone resorption beyond initial bone remodeling (Albrektsson and Isidor 1994).

Since then, following decades of clinical research in implant dentistry, the patient-based estimated weighted mean prevalence and range of peri-implant diseases have been reported in systematic reviews with meta-analyses (Mombelli and coworkers 2012; Derks and Tomasi 2015). The mean prevalence for peri-implant mucositis was reported at 43% (range: 19 – 65%), whereas for peri-implantitis it was estimated at 22% (range: 1 – 47%) (Derks and Tomasi 2015). In addition, outcomes from cross-sectional studies (Aguirre-Zorzano and coworkers 2015; Daubert and coworkers 2015; Dalago and coworkers 2017; Konstantinidis and coworkers 2015; Rokn and coworkers 2017; Schwarz and coworkers 2017a) not included in the systematic review by Derks and Tomasi (2015) reported a similar prevalence for peri-implantitis, ranging from 12.9 to 26%.

A large cross-sectional study identified patients from the Swedish population who had implants in situ for 9 years (n > 24,716). 596 patients attended a clinical examination out of 900 invitees and the prevalence of moderate to severe peri-implantitis (defined as presence of BoP, suppuration and > 2 mm of peri-implant bone loss) was 14.5% (Derks and coworkers 2016a).

More recently, the prevalence of peri-implant mucositis and peri-implantitis was reported in a case-series study with a 21- to 26-year follow-up. In that study, 86 out of 294 patients rehabilitated with implants were re-examined on average 23.3 years later. The results indicated that 54.7% of patients were diagnosed with peri-implant mucositis and 22.1 % with peri-implantitis (Renvert and coworkers 2018a).

In another large study assessing the electronic health records of patients treated in a dental school in the USA, a prevalence of peri-implantitis of 35% was reported using a threshold of > 2 mm bone loss (Kordbacheh Changi and coworkers 2019).

In summary, a wide range of prevalence of peri-implant diseases is apparent. The heterogeneity in reporting may be influenced by factors such as definitions and thresholds used, time point of assessment, level of reporting (i.e., implant- vs. patient-based), compliance of patient sample with supportive periodontal therapy (SPT), and characteristics of patient samples and implant recipient sites, making comparisons among studies difficult.

5.1 Factors Influencing the Reported Prevalence of Peri-Implant Diseases

The lack of clear thresholds defining peri-implant diseases has resulted in numerous case definitions in studies addressing disease prevalence.

The consensus report of the 8th European Workshop on Periodontology (EWP) in 2012 emphasized the importance of reporting the prevalence of peri-implant diseases at the patient-level, rather than at the implant-level (Sanz and Chapple 2012). The lack of patient-based analyses in some studies was highlighted in a systematic review on the quality of studies reporting prevalence, incidence, and risk factors of peri-implant diseases (Tomasi and Derks 2012).

Furthermore, different thresholds for marginal bone loss assessment and reference time points from which bone loss occurred have been used, making it difficult to compare study populations. This has also been reflected in the systematic review by Derks and Tomasi (2015), where one study considered a threshold of 5 mm marginal bone loss as a case definition reporting a 1% prevalence of peri-implantitis (Zetterqvist and coworkers 2010), whereas in another study a threshold of 0.4 mm marginal bone loss was used resulting in a 47% prevalence of peri-implantitis (Koldsland and coworkers 2010).

In a cross-sectional analysis of a randomly selected sample of 588 Swedish citizens, peri-implantitis was defined as the presence of bleeding on probing (BoP) and/or suppuration and marginal bone loss of > 0.5 mm (Derks and coworkers 2016a). In that study, a 45% patient-based prevalence of peri-implantitis was reported after 9 years of loading (Derks and coworkers 2016a). A threshold of > 2 mm of marginal bone loss was defined as moderate to severe peri-implantitis, resulting in a prevalence of 14.5% of patients (Derks and coworkers 2016a).

An additional factor observed in most studies reporting on the prevalence of peri-implant diseases is that the analyses are based on convenience patient samples from universities or private practices with limited numbers of patients included, rather than on large randomly selected cohorts (Roos-Jansåker and coworkers 2006a; Tomasi and Derks 2012). This limitation may account for selection bias and impacts on external validity in terms of true prevalence of peri-implant diseases. Only a limited number of studies reporting on the prevalence of peri-implant diseases have included both patients treated in private and University settings (Derks and coworkers 2016a; Schwarz and coworkers 2017a; Renvert and coworkers 2014) or analyzed a randomly selected population sample (Derks and coworkers 2016a).

The results of a 10-year prospective study in patients treated for periodontitis, but not complying with regular supportive periodontal therapy (SPT), showed significantly higher proportions of implant sites with bleeding on probing (BoP), greater mean deepest probing depths (PD) at implant sites, and higher frequency of implants with ≥ 1 site with PD ≥ 6 mm compared with patients compliant with regular SPT (Roccuzzo and coworkers 2014).

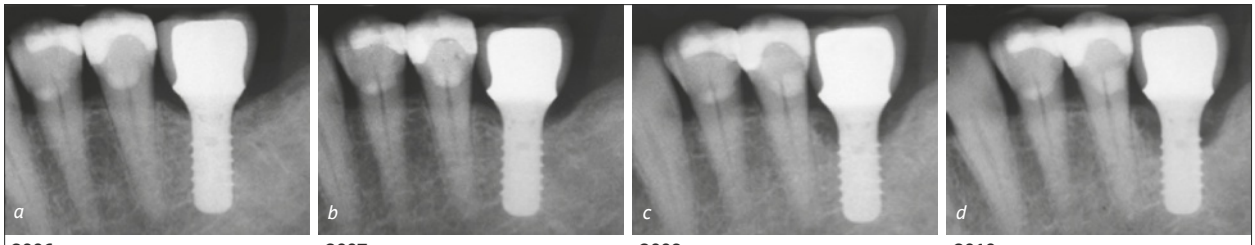
Interestingly, patients who received implant-supported prostheses following periodontal therapy displayed a higher rate of compliance with scheduled SPT appointments compared with patients who underwent periodontal therapy alone without receiving implants (Cardaropoli and Gaveglio 2012).

Patient-related factors associated with a lack of compliance with SPT were reported in a recent systematic review (Amerio and coworkers 2020). Age, gender, and socio-economic status were not found to be significant predictors of patients' compliance with SPT. While patients with a history of treated periodontitis were found to be more likely to comply with SPT, smokers were associated with a low level of compliance. The results also indicated that the main patient-reported reasons for non-compliance with SPT were lack of information and motivation (Amerio and coworkers 2020).

Finally, outcomes of a systematic review including eight case series indicated that implants placed in augmented sites may yield higher rates of peri-implantitis (17.8 vs. 10.3%) and implant loss (3.6 vs. 2.5%) compared with implants placed in pristine bone after a mean observation period of at least ten years (Salvi and coworkers, 2018). These differences, however, were not statistically significant. Based on differences in characteristics of patient samples, materials, and surgical protocols used for augmentation procedures and implant designs, the reported rates should be interpreted with caution (Salvi and coworkers 2018).

In conclusion, it should be expected that the new classification of peri-implant diseases and conditions introduced at the 2017 World Workshop (Berglundh and coworkers 2018a) and outlined in Chapter 2 will help standardize case definitions and minimize differences in reporting of epidemiologic data, thus providing a more globally consistent picture of the prevalence of peri-implant diseases.

5.2 Onset and Progression of Peri-Implant Diseases



Figs 1a-d Implant site 36. Radiographs illustrating progressive marginal bone loss from 2006 to 2010. The implant was treated in 2010.

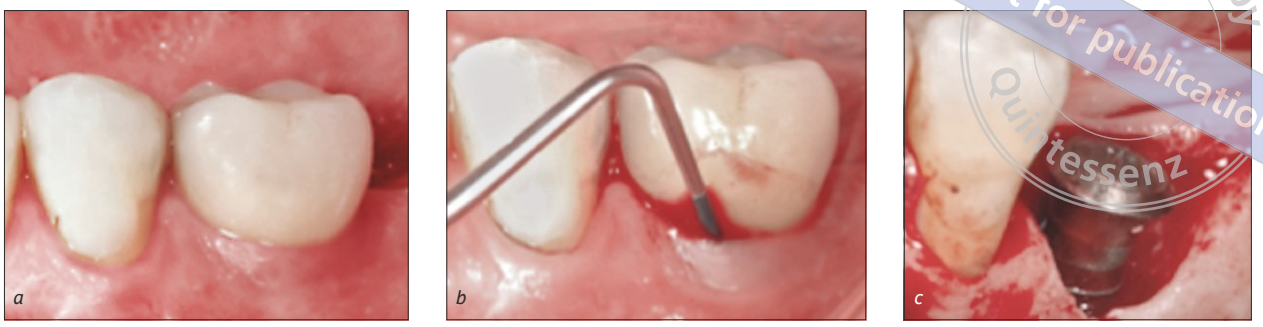
Peri-implant mucositis may be present for extended periods of time without progressing to peri-implantitis. Conversion from peri-implant mucositis to peri-implantitis in humans is impossible to study in an experimental set-up for obvious ethical reasons.

The assessment of the shift from peri-implant mucositis to peri-implantitis would require the detection of early signs of marginal bone loss. Longitudinal retrospective studies could be used to identify the time of onset of peri-implantitis by its pattern of progression in radiographs.

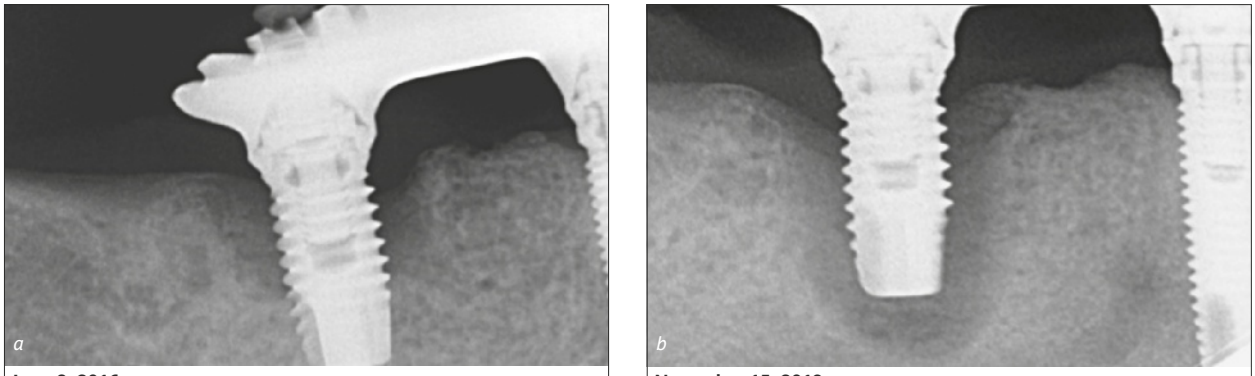
Such an assessment was undertaken in a retrospective study including a random sample of 596 patients attending a nine-year clinical and radiographic follow-up examination (Derks and coworkers 2016). Peri-implant marginal bone loss could be assessed by comparing radiographs taken one year following delivery of restoration (baseline) with those taken at the nine-year follow-up examination. Of the patients who developed peri-implantitis 81% presented with one or more implants with detectable signs of bone loss (i.e. at least 0.5 mm) within three years of delivery of the restoration. Only 4% of patients experienced onset of peri-implantitis five years from baseline.

The results of this study clearly indicated that the onset of peri-implantitis occurred early following implant loading and that the progression of the disease followed a non-linear accelerating pattern (Derks and coworkers 2016b) (Figs 1a-d and 2a-c). Left untreated, peri-implantitis may progress rapidly, leading to complete loss of osseointegration (Fig 3). The progression of peri-implantitis appears to be faster than that observed in periodontitis.

This in turn highlights the importance of early diagnosis of peri-implantitis and the implementation of therapeutic steps.



Figs 2a-c Implant site 36. Bleeding on probing and a peri-implant circumferential intrabony defect observed intrasurgically in 2010.



Figs 3a-b Radiographic evidence of rapid progressive bone loss leading to complete loss of osseointegration. The patient declined treatment of the peri-implantitis. (a) Radiograph (2016) illustrating marginal bone loss at implant site 47. (b) Radiograph (2019) illustrating progressive bone loss three years later, resulting in complete loss of osseointegration of implant site 47.

Dental implants are used routinely throughout the world to replace missing teeth. With the broadening of treatment options and an increasing number of clinicians providing implant therapy, it is important to ensure that the treatment methods used meet the highest clinical standards.

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