Received: 20 December 2017 | Revised: 6 February 2018 | Accepted: 1 March 2018

DOI: 10.1111/jcpe.12957

2017 WORLD WORKSHOP

WILEY Journal of Clinical Periodontology

Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions

Tord Berglundh[1] | Gary Armitage[2] | Mauricio G. Araujo[3] | Gustavo Avila-Ortiz[4] | Juan Blanco[5] | Paulo M. Camargo[6] | Stephen Chen[7] | David Cochran[8] | Jan Derks[1] | Elena Figuero[9] | Christoph H.F. Hämmerle[10] | Lisa J.A. Heitz-Mayfield[11] | Guy Huynh-Ba[8] | Vincent Iacono[12] | Ki-Tae Koo[13] | France Lambert[14] | Laurie McCauley[15] | Marc Quirynen[16] | Stefan Renvert[17] | Giovanni E. Salvi[18] | Frank Schwarz[19] | Dennis Tarnow[20] | Cristiano Tomasi[1] | Hom-Lay Wang[15] | Nicola Zitzmann[21]

[1]Department of Periodontology, Institute of Odontology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

[2]University of California San Francisco, San Francisco, CA, USA

[3]State University of Maringa, Parana, Brazil

[4]University of Iowa, Iowa City, IA, USA

[5]Universidad Santiago de Compostela, Santiago, Spain

[6]University of California Los Angeles, Los Angeles, CA, USA

[7]University of Melbourne, Melbourne, Australia

[8]University of Texas Health Science Center, San Antonio, TX, USA

[9]Universidad Complutense, Madrid, Spain

[10]Clinic of Fixed and Removable Prosthodontics and Dental Material Science, University of Zurich, Zurich, Switzerland

[11]University of Sydney, Sydney, Australia

[12]Stony Brook University, Stony Brook, NY, USA

[13]Seoul National University, Seoul, South Korea

[14]Department of Periodontology and Oral Surgery, University of Liège, Liège, Belgium

[15]School of Dentistry, University of Michigan, Ann Arbor, MI, USA

[16]Leuven University, Flanders, Belgium

[17]Kristianstad University, Kristianstad, Sweden

[18]Department of Periodontology, University of Bern, Bern, Switzerland

[19]Department of Oral Surgery and Implantology, Carolinum, Goethe University, Frankfurt, Germany

[20]Columbia University, New York, NY, USA

[21]Department of Reconstructive Dentistry, University of Basel, Basel, Switzerland

Correspondence
Prof. Tord Berglundh, Department of Periodontology, Institute of Odontology, Sahlgrenska Academy, University of Gothenburg, PO Box 450, 405 30 Gothenburg, Sweden.
Email: tord.berglundh@odontologi.gu.se

Sources of Funding: The workshop was planned and conducted jointly by the American Academy of Periodontology and the European Federation of Periodontology with financial support from the American Academy of Periodontology Foundation, Colgate, Johnson & Johnson Consumer Inc., Geistlich Biomaterials, SUNSTAR, and Procter & Gamble Professional Oral Health.

The proceedings of the workshop were jointly and simultaneously published in the *Journal of Periodontology* and *Journal of Clinical Periodontology*.

Abstract

A classification for peri-implant diseases and conditions was presented. Focused questions on the characteristics of peri-implant health, peri-implant mucositis, peri-implantitis, and soft- and hard-tissue deficiencies were addressed.

Peri-implant health is characterized by the absence of erythema, bleeding on probing, swelling, and suppuration. It is not possible to define a range of probing depths compatible with health; Peri-implant health can exist around implants with reduced bone support.

The main clinical characteristic of peri-implant mucositis is bleeding on gentle probing. Erythema, swelling, and/or suppuration may also be present. An increase in probing depth is often observed in the presence of peri-implant mucositis due to swelling or decrease in probing resistance. There is strong evidence from animal and human experimental studies that plaque is the etiological factor for peri-implant mucositis.

Peri-implantitis is 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. Peri-implantitis sites exhibit clinical signs of inflammation, bleeding on probing, and/or suppuration, increased probing depths and/or recession of the mucosal margin in addition to radiographic bone loss.

The evidence is equivocal regarding the effect of keratinized mucosa on the long-term health of the peri-implant tissue. It appears, however, that keratinized mucosa may have advantages regarding patient comfort and ease of plaque removal.

Case definitions in day-to-day clinical practice and in epidemiological or disease-surveillance studies for peri-implant health, peri-implant mucositis, and peri-implantitis were introduced. The proposed case definitions should be viewed within the context that there is no generic implant and that there are numerous implant designs with different surface characteristics, surgical and loading protocols. It is recommended that the clinician obtain baseline radiographic and probing measurements following the completion of the implant-supported prosthesis.

KEYWORDS
case definition, dental implant, hard tissue deficiencies, peri-implant mucositis, peri-implant tissues, peri-implantitis, soft tissue deficiencies

The objective of Workgroup 4 was to present a classification on peri-implant diseases and conditions. Five position papers describing the characteristics of peri-implant health,[1] peri-implant mucositis,[2] peri-implantitis,[3] soft and hard tissue deficiencies[4] and case definitions and diagnostic considerations[5] were prepared prior to the workshop.

In preparing this consensus report regarding the criteria for peri-implant health and disease it was recognized that there are a number of somewhat unusual peri-implant problems (e.g., implant fractures) and other conditions that may mimic or share certain clinical features with biofilm-associated peri-implant diseases. The following assumptions have been made: 1) complete medical-dental histories have been obtained including details on implant-supported reconstructions; and 2) an appropriate differential diagnostic analysis has been performed.

The following questions and case definitions are intended to apply to situations in which the clinician has reasons to believe that biofilms on implant surfaces are the main etiological exposures associated with the development of peri-implant mucositis and peri-implantitis. It is important to emphasize that there are major patient-specific differences in inflammatory responses to the microbial challenge of bacterial communities that reside on implants. In addition, it has been assumed that the implants were properly placed and subsequently integrated with soft and hard tissues.

PERI-IMPLANT HEALTH

1. *What are the clinical characteristics of a healthy peri-implant site?*
   In health, the peri-implant site is characterized by absence of erythema, bleeding on probing, swelling and suppuration.
2. *What are the main clinical differences between healthy peri-implant and periodontal tissues?*
   In health, there are no visual differences between peri-implant and periodontal tissues. However, the probing depths are usually greater at implant versus tooth sites. The papillae at the interproximal sites of an implant may be shorter than the papillae at interproximal tooth sites.
3. *What clinical methods and instruments should be used to detect the presence or absence of inflammation at an implant site?*
   The clinical methods to detect the presence of inflammation should include visual inspection, probing with a periodontal probe, and digital palpation.
4. *Why is it important to probe peri-implant tissues during a complete oral examination?*
   It is necessary to probe peri-implant tissues to assess the presence of bleeding on probing, and to monitor probing depth changes and mucosal margin migration. This assessment may alert the clinician to the need for therapeutic intervention. There is evidence that probing of the peri-implant tissue using a light probing force is a safe and important component of a complete oral examination.
5. *What peri-implant probing depths are compatible with peri-implant health?*
   It is not possible to define a range of probing depths compatible with health; of more importance are the clinical signs of inflammation.
6. *Can peri-implant health exist around implants with reduced bone support?*
   Yes, peri-implant tissue health can exist around implants with reduced bone support.
7. *What are the histological characteristics of a healthy peri-implant site?*
   The histological characteristics of a healthy peri-implant site are derived mainly from animal studies. The healthy peri-implant mucosa averages 3 to 4 mm in height and is covered by either a keratinized (masticatory mucosa) or non-keratinized epithelium (lining mucosa). The portion of the peri-implant mucosa that is facing the implant/abutment contains a "coronal" portion that is lined by a sulcular epithelium and a thin junctional epithelium, and a more "apical" segment in which the connective tissue is in direct contact with the implant surface. The connective tissue lateral to the sulcular epithelium harbors a small infiltrate of inflammatory cells. Most of the intrabony part of the implant is in contact with mineralized bone, while the remaining portion faces bone marrow, vascular structures, or fibrous tissue.
8. *What are the main histological differences between healthy peri-implant and periodontal tissues?*

   Compared to the periodontium, the peri-implant tissues do not have cementum and periodontal ligament. The peri-implant epithelium is often longer and in the connective tissue zone there are no inserting fibers into the implant surface. The peri-implant tissues are less vascularized in the zone between the bone crest and the junctional epithelium when compared to the connective tissue zone of the periodontium.

PERI-IMPLANT MUCOSITIS

1. *What are the clinical characteristics of peri-implant mucositis?*
   The main clinical characteristic of peri-implant mucositis is bleeding on gentle probing. Erythema, swelling and/or suppuration may also be present.
2. *Does peri-implant mucositis exist in the absence of clinical signs of inflammation?*
   Clinical signs of inflammation are necessary for a diagnosis of peri-implant mucositis.
3. *How does probing depth relate to the detection of peri-implant mucositis?*
   An increase in probing depth is often observed in the presence of peri-implant mucositis due to swelling or decrease in probing resistance.
4. *What is the evidence for plaque as the main etiological factor for peri-implant mucositis?*
   There is strong evidence from animal and human experimental studies that plaque is the etiological factor for peri-implant mucositis.
5. *Does non–plaque-induced peri-implant mucositis exist?*
   There is limited evidence for non–plaque-induced peri-implant mucositis.
6. *Can peri-implant mucositis resolve?*
   There is evidence from experimental human studies that peri-implant mucositis can resolve. Resolution of the clinical signs of inflammation may take more than 3 weeks following reinstitution of plaque/biofilm control.
7. *What are the environmental and patient-specific risk indicators for peri-implant mucositis?*
   The major etiological factor is plaque accumulation. Host response to the bacterial challenge may vary between patients. Smoking, diabetes mellitus, and radiation therapy may modify the condition.
8. *What are the histological characteristics of peri-implant mucositis?*
   Peri-implant mucositis is characterized by a well-defined inflammatory lesion lateral to the junctional/pocket epithelium with an infiltrate rich in vascular structures, plasma cells, and lymphocytes. The inflammatory infiltrate does not extend "apical" of the junctional/pocket epithelium into the supracrestal connective tissue zone.

PERI-IMPLANTITIS

1. *What is peri-implantitis?*
   Peri-implantitis is 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.
2. *What is the evidence for plaque/biofilm as a principal etiological factor for peri-implantitis?*
   There is evidence from observational studies that patients exhibiting poor plaque control and not attending regular maintenance therapy are at higher risk of developing peri-implantitis. Studies on treatment of peri-implantitis reveal that anti-infective treatment strategies are successful in decreasing soft tissue inflammation and in suppressing disease progression.
3. *What are the clinical characteristics of peri-implantitis?*
   Peri-implantitis sites exhibit clinical signs of inflammation, bleeding on probing and/or suppuration, increased probing depths and/or recession of the mucosal margin in addition to radiographic bone loss compared to previous examinations. At sites presenting with peri-implantitis, probing depth is correlated with bone loss and is, hence, an indicator for the severity of disease. It is important to recognize that rate of progression of bone loss may vary between patients.
4. *What are the histological characteristics of peri-implantitis?*
   Peri-implantitis lesions extend apical of the junctional/pocket epithelium and contain large numbers and densities of plasma cells, macrophages and neutrophils. In addition, peri-implantitis lesions are larger than those at peri-implant mucositis sites.
5. *Are there any specific microbiological and immunological characteristics of peri-implantitis?*
   No specific or unique bacteria or proinflammatory cytokines have been identified.
6. *What is the evidence for peri-implant mucositis being the precursor of peri-implantitis?*
   Peri-implant mucositis is assumed to precede peri-implantitis. Data indicate that patients diagnosed with peri-implant mucositis may develop peri-implantitis, especially in the absence of regular maintenance care. However, the features or conditions characterizing the progression from peri-implant mucositis to peri-implantitis in susceptible patients have not been identified.
7. *What is known about the onset and progression pattern of peri-implantitis?*
   The onset of peri-implantitis may occur early during follow-up as indicated by radiographic data. Peri-implantitis, in the absence of treatment, seems to progress in a non-linear and accelerating pattern. Data suggest that the progression of peri-implantitis appears to be faster than that observed in periodontitis.
8. *What are the major risk indicators for peri-implantitis?*
   There is strong evidence that there is an increased risk of developing peri-implantitis in patients who have a history of severe periodontitis, poor plaque control, and no regular maintenance care after implant therapy. Data identifying smoking and diabetes as potential risk indicators for peri-implantitis are inconclusive.
   Implants that have been placed under less than ideal circumstances are often encountered in day-to-day practice. As a result, there may be an increased prevalence of peri-implantitis associated with these situations.
   There is some limited evidence linking peri-implantitis to factors such as post-restorative presence of submucosal cement and positioning of implants that does not facilitate oral hygiene and maintenance. The role of peri-implant keratinized mucosa, occlusal overload, titanium particles, bone compression necrosis, overheating, micromotion and biocorrosion as risk indicators for peri-implantitis remains to be determined.
   There is a high priority to conduct studies that are designed to develop diagnostic, preventive, and intervention strategies for the management of these peri-implant issues.
9. *Does progressive crestal bone loss around implants occur in the absence of soft tissue inflammation?*
   Observational studies have indicated that crestal bone level changes at implants are typically associated with clinical signs of inflammation. However, there are situations in which peri-implant bone loss may occur due to iatrogenic factors, including malpositioning of the implant or surgical trauma.

HARD- AND SOFT-TISSUE DEFICIENCIES

1. *What are the main factors associated with hard- and soft-tissue deficiencies at potential implant sites?*
   The healing process following tooth loss leads to diminished dimensions of the alveolar process/ridge representing hard- and soft-tissue deficiencies. Larger deficiencies may occur at sites exposed to the following factors: loss of periodontal support, endodontic infections, longitudinal root fractures, thin buccal bone plates, buccal/lingual tooth position in relation to the arch, extraction with additional trauma to the tissues, injury, pneumatization of the maxillary sinus, medications, and systemic diseases reducing the amount of naturally formed bone, agenesis of teeth, pressure from soft-tissue supported removable prosthesis, and combinations.
2. *What factors are associated with recession of the peri-implant mucosa?*
   The principal factors for recession of the peri-implant mucosa are malpositioning of implants, lack of buccal bone, thin soft tissue, lack of keratinized tissue, status of attachment of the adjacent teeth and surgical trauma.
3. *Does the presence/absence of keratinized mucosa play a role in the long-term maintenance of peri-implant health?*
   The evidence is equivocal regarding the effect of keratinized mucosa on the long-term health of the peri-implant tissue. It appears, however, that keratinized mucosa may have advantages regarding patient comfort and ease of plaque removal.

4. *What is the role of the peri-implant bone in giving form to the peri-implant soft tissues?*

   The papilla height between implants and teeth is affected by the level of the periodontal tissues on the teeth adjacent to the implants. The height of the papilla between implants is determined by the bone crest between the implants. Results are equivocal whether the buccal bone plate is necessary for supporting the buccal soft tissue of the implant in the long-term.

CASE DEFINITIONS AND DIAGNOSTIC CONSIDERATIONS

The following case definitions and characteristics of peri-implant health, peri-implant mucositis, and peri-implantitis should be viewed within context of several potential confounding factors.

It is known that there is no generic implant and that there are numerous implant designs with different surface characteristics, surgical and loading protocols. The degree of physiological remodeling after implant placement may vary and will determine the crestal level of bone expected in peri-implant health. The amount of remodeling will also be influenced by a number of local and systemic factors. Clinicians should be aware that extensive peri-implant bone loss may also be reflective of the development of peri-implantitis during the remodeling phase.

It is recommended that the clinician obtain baseline radiographic and probing measurements following the completion of the implant-supported prosthesis. An additional radiograph after a loading period should be taken to establish a bone level reference following physiological remodeling. If the patient presents for the first time with an implant-supported prosthesis the clinician should try to obtain clinical records and previous radiographs in order to assess changes in bone levels.

How do we define a case of peri-implant health in day-to-day clinical practice and teaching situations?

Diagnosis of peri-implant health requires:

- 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.

It should be noted that probing depths depend on the height of the soft tissue at the location of the implant. Furthermore, peri-implant tissue health can exist around implants with variable levels of bone support.

How do we define a case of peri-implant mucositis in day-to-day clinical practice and teaching situations?

Diagnosis of peri-implant mucositis requires:

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

It should be noted that visual signs of inflammation can vary and that peri-implant mucositis can exist around implants with variable levels of bone support.

How do we define a case of peri-implantitis in day-to-day clinical practice and teaching situations?

Diagnosis of peri-implantitis requires:

- Presence of bleeding and/or suppuration on gentle probing.
- Increased probing depth compared to previous examinations.
- Presence of bone loss beyond crestal bone level changes resulting from initial bone remodeling.

In the absence of previous examination data diagnosis of peri-implantitis can be based on the combination of:

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

It should be noted that visual signs of inflammation can vary and that recession of the mucosal margin should be considered in the probing depth evaluation.

How do we define a case of peri-implant health and peri-implant mucositis in epidemiological or disease surveillance studies?

The same criteria used to define peri-implant health and peri-implant mucositis in day-to-day practice should be applied in epidemiological studies.

How do we define a case of peri-implantitis in epidemiological or disease surveillance studies?

Diagnosis of peri-implantitis requires:

- Presence of bleeding and/or suppuration on gentle probing.
- Increased probing depth compared to previous examinations.
- Presence of bone loss beyond crestal bone level changes resulting from initial bone remodeling. Epidemiological studies need to take into account the error of measurements in relation to assessments of bone level changes. Bone loss should be reported using thresholds exceeding the measurement error (mean 0.5 mm).

Epidemiological studies should ideally include previous examinations performed after the first year of loading. In the absence of previous radiographic examinations, bone levels ≥3 mm apical of the most coronal portion of the intra-osseous part of the implant together with bleeding on probing are consistent with the diagnosis of peri-implantitis.

ACKNOWLEDGMENTS AND DISCLOSURES

Workshop participants filed detailed disclosure of potential conflicts of interest relevant to the workshop topics, and these are kept on file. The authors receive, or have received, research funding, consultant fees, and/or lecture compensation from the following companies: BioHorizons, Dentsply Sirona, Geistlich Pharma, Intra-Lock, ITI Foundation, J. Morita, LaunchPad Medical, Maxillent, Medtronic, Osteogenics Biomedical, Osteology Foundation, Straumann, and SUNSTAR.

REFERENCES

1. Araujo MG, Lindhe J. Peri-implant health. *J Clin Periodontol*. 2018;*45*(Suppl 20):S230–S236.
2. Heitz-Mayfield LJA, Salvi GE. Peri-implant mucositis. *J Clin Periodontol*. 2018;*45*(Suppl 20):S237–S245.
3. Schwarz F, Derks J, Monje A, Wang H-L. Peri-implantitis. *J Clin Periodontol*. 2018;*45*(Suppl 20):S246–S266.
4. Hämmerle CHF, Tarnow D. The etiology of hard- and soft-tissue deficiencies at dental implants: a narrative review. *J Clin Periodontol*. 2018;*45*(Suppl 20):S267–S277.
5. Renvert S, Persson GR, Pirih FQ, Camargo PM. Peri-implant health, peri-implant mucositis, and peri-implantitis: case definitions and diagnostic considerations. *J Clin Periodontol*. 2018;*45*(Suppl 20):S278–S285.

How to cite this article: Berglundh T, Armitage G, et al. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Clin Periodontol*. 2018;45(Suppl 20):S286–S291. https://doi.org/10.1111/jcpe.12957

FIGURE 1 Participants of Workgroup 4