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Cleaning of titanium dental implant surfaces
Louropoulou, A.

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Chapter 8

Prevention and Treatment of Peri-implant diseases
- An Epitome of the Dutch Guideline -

A. Louropoulou
G.A. van der Weijden
Introduction

Implant therapy is a useful and successful extension of the dental armamentarium for the treatment of patients with missing teeth. However, clinicians should expect to see both biological and technical complications in their daily practice (Heitz-Mayfield et al. 2014). This paper is based on a clinical guideline that has recently been published in the Netherlands on the prevention and management of biological complications. The Dutch Society of Periodontology and the Dutch Society of Implantology appointed the working group. The merit of this working group was to provide answers and make recommendations for clinical practice focusing on the aspects of diagnosis, prevention and treatment of peri-implant diseases. The guideline was developed taking into account the Appraisal of Guidelines for Research and Evaluation (AGREE) II Instrument (Brouwers et al. 2010) and a Dutch guideline for the development of guidelines (Richtlijn voor Richtlijnen, 2012).

Peri-implant diseases may occur in two forms, peri-implant mucositis and peri-implantitis (Lang & Berglundh 2011). Peri-implant mucositis is defined as the presence of inflammation in the mucosa around implants without loss of supportive bone. In contrast, peri-implantitis also affects the supporting bone, causing progressive bone loss beyond the normal biologic remodelling (AAP-Academy-Report, 2013). Currently, the prevalence of peri-implant diseases represents a controversial issue (Tarnow, 2016). Estimates of patient-based weighted mean prevalences and ranges for peri-implant mucositis and peri-implantitis were reported in a recent systematic review. The prevalence for peri-implant mucositis was reported to be 43% (range, 19% to 65%), whereas for peri-implantitis this amounted to 22% (range, 1% to 47%) (Derks & Tomasi 2015). Differences in case definition, with varying thresholds for the assessment of bone loss and reference time points from which the bone loss occurred, result in a wide range of prevalence of peri-implant diseases reported in the literature. It is, therefore, difficult to globally estimate the true magnitude of the disease (Salvi et al. 2017).

The presence of a biofilm that contains pathogens plays an important role in the initiation and progression of peri-implant diseases (Heitz-Mayfield & Lang 2010). Microorganisms may be present but they are not always the origin of the problem (Mombelli & Décailliet 2011). Peri-implant diseases may be initiated or maintained by iatrogenic factors e.g. cement remnants, inadequate restoration-abutments seating, over-contouring of restorations, implant mal-positioning, technical complications such as loosening of a screw or fracture of implant components. Furthermore, bone loss induced at the time of implant placement by traumatizing the pristine bone beyond its adaptive capacity may also persist (Lang & Ber-
In a recent review paper (Vasconcelos et al. 2016), it has been concluded that metal particles and metal ions may induce immunologic response that may lead to bone loss and implant failure. Moreover, patient-related factors, like untreated or refractory periodontitis, systemic diseases, smoking, level of oral hygiene, compliance with maintenance and site-related factors e.g. poor bone quality are important parameters that may contribute to the initiation and/or progression of peri-implant diseases (De Bruyn et al. 2016).

**Risk indicators for peri-implant disease**

There is substantial evidence that poor oral hygiene, smoking and history of periodontitis are important risk indicators for peri-implant diseases (Heitz-Mayfield, 2008).

*History of periodontitis*

Patients with a history of periodontitis are at greater risk for peri-implant diseases (van der Weijden et al. 2005; Karoussis et al. 2007; Quirynen et al. 2007). In periodontitis susceptible patients, residual pockets (PPD ≥ 5 mm) at the end of active periodontal therapy were found to represent a significant risk for the development of peri-implantitis and implant loss. Moreover, patients developing re-infections during supportive periodontal treatment were found to be at greater risk for peri-implantitis and implant loss than patients maintaining a stable periodontal condition (Pjetursson et al. 2012). Successful treatment of periodontitis prior to implant placement lowers the risk for peri-implantitis (Renvert & Quirynen 2015).

*Oral Hygiene/Accessibility to clean*

A prospective study reported an association between poor oral hygiene and peri-implant bone loss at 10-year follow-up (Lindquist et al. 1997). Very poor oral hygiene has been associated with peri-implantitis with an OR=14.3, 95% CI 9.1–28.7 (Ferreira et al. 2006). Furthermore, the accessibility for proper oral hygiene at the implant site seems to be related to the presence or absence of peri-implantitis (Serino & Ström 2009). It is, therefore, very important to educate the patients rehabilitated with dental implants in proper plaque control and to establish regular maintenance. Prosthesis design must allow accessibility for proper oral hygiene at the implants. Whenever possible margins of implant-supported restorations should be placed at or above the mucosal margin to facilitate access for plaque control. Implant-supported restorations with poor access for plaque removal should be adjusted or replaced by restorations that allow for optimal oral hygiene (Salvi & Ramseier 2015).
Smoking and alcohol consumption
It is indicated that smokers have an enhanced risk for biologic complications. Smoking has been associated with the onset of peri-implantitis and smokers showed more marginal bone loss compared to non-smokers (Strietzel et al. 2007; Chrcanovic et al. 2015; Renvert & Quirynen 2015). Regarding alcohol consumption, one prospective study reported that peri-implant marginal bone loss was significantly related to a daily consumption of > 10g alcohol (Galindo-Moreno et al. 2005).

Diabetes mellitus
Diabetes may be associated with peri-implantitis (Renvert & Quirynen 2015). A systematic review on dental implants and diabetes mellitus reported that, in the long-term observation, peri-implant inflammation seems to be increased in diabetic patients, especially if diabetes is poorly controlled (Naujokat et al. 2016).

Genetic traits
There are studies showing a synergistic effect between genetic traits and smoking on the development of peri-implant diseases (Feloutzis et al. 2003; Gruica et al. 2004; Jansson et al. 2005). The negative effect of smoking seems to be more pronounced in patients with a positive IL-1 genotype (Feloutzis et al. 2003). Although genetic traits may influence the inflammatory response, available data on the relationship between peri-implantitis and genetic traits are at present unclear (Renvert & Quirynen 2015).

Occlusal overload
Implants are considered less tolerable to non-axial forces compared to teeth because of the lack of periodontal ligament (AAP-Academy-Report, 2013). Excessive stress can cause micro-fractures within bone and eventually bone loss (Stanford & Brand 1999). Occlusal overload was found to be positively associated with marginal bone loss around implants (Fu et al. 2012). It has also been suggested that bruxism may be associated with an increased risk of implant failure (Chrcanovic et al. 2016). The AAP-Academy Report (2013) stated that the influence of occlusal overload on peri-implantitis needs further investigation. In this respect, also a more precise definition of occlusal overload is needed. Although hard evidence for the impact of occlusal overload on peri-implantitis is lacking, it seems advisable to include an evaluation of the patients’ occlusion during maintenance visits (Renvert & Quirynen 2015).
Implant surface

Dental implants are available with a range of surface characteristics. So far, there is no evidence available that the type of implant surface can have a significant effect on the initiation of peri-implantitis. However, there is some evidence that surface characteristics may have an effect on the progression of established peri-implantitis (Renvert et al. 2011). Data available from human studies suggest that implants with relatively smooth (machined) surfaces may be less prone to bone loss due to chronic infection than implant with much rougher surfaces (titanium plasma sprayed) (Renvert et al. 2011; Esposito et al. 2014). Furthermore, animal studies, whereby a ligature-induced peri-implantitis model was used, suggest that some moderately rough surfaces (Sa = 1.1-2.0 μm) might be more susceptible to disease progression than other surfaces (Berglundh et al. 2007; Albouy et al. 2008, 2009).

Keratinized mucosa

A recent systematic review concluded that the presence of an adequate zone of keratinized tissue (≥2mm) around the implant-supported restoration might be necessary because it has been associated with better peri-implant tissue health (Brito et al. 2014).

Excess cement

Excess cement may act as a foreign body and thus provoke an inflammatory reaction in the peri-implant tissues. The use of cement-retained implant restorations was found to frequently result in leaving excess cement in peri-implant tissues despite of careful clinical control following cementation of the crown (Linkevicius et al. 2013b); the deeper the position of the crown margin, the greater the amount of undetected cement discovered (Linkevicius et al. 2013a). Although few papers exist on the association between excess cement and peri-implantitis, the data clearly indicate that excess cement may be a contributing factor to the development of peri-implantitis (Renvert & Quirynen 2015).

Diagnosis of peri-implant diseases

After the delivery of the definite implant-supported restoration, baseline data representing homeostasis should be established (Lang & Berglundh 2011). For this a radiograph should be obtained to determine alveolar bone level after physiologic remodelling, and peri-implant probing assessments should be performed. According to the Dutch approach, a clinical
photograph may help to visualize changes of the soft peri-implant tissues and to evaluate
the position, form and thickness of the peri-implant mucosa. Recorded baseline data will be
the reference from which the peri-implant condition can be followed in subsequent examina-
tions and early development of peri-implant disease can be timely recognized (Table 1).

Radiographs
The time of the prosthesis installation should be chosen to obtain a radiograph. This radi-
ograph can also be used to control the proper fitting of the restoration/abutment or the pres-
ent of cement remnants, in case of cement-retained restorations. A new radiograph should
be made one year after the prosthesis installation in order to determine alveolar bone level
after physiologic remodelling and establish radiographic baseline after this remodelling. It
is assumed that further bone loss occurring after this initial remodelling is mainly due to
bacterial infection (Lang & Berglundh 2011).

A radiograph taken some years after the installation of the implant-supported restora-
tion without any possible reference to a baseline radiograph cannot be used to diagnose
disease, or to assess progressing marginal bone loss. This clearly requires a series of radio-
graphs, taken at different time points, displaying ongoing loss of marginal bone. The latter
is an important criterion for the diagnosis of peri-implantitis (Albrektsson et al. 2016). In
the absence of previous radiographic records, a vertical distance of 2 mm from the expected
marginal bone level following remodelling has been suggested as an appropriate threshold
level, provided peri-implant inflammation was evident (Sanz & Chapple 2015).

Intraoral and panoramic radiographs are widely used for peri-implant diagnosis and
both are reliable to assess bone levels around dental implants (Kullman et al. 2007). However,
intraoral radiographs provide a more detailed picture and higher resolution and, therefore,
should be preferred. Nonetheless, both methods cannot monitor facial and lingual bone lev-
els, have low sensitivity in the detection of early bone loss and underestimate the marginal
bone level (De Smet et al. 2002). In addition, radiographs do not provide information on the
condition of the soft tissues. Hence, a thorough clinical examination is mandatory for com-
plete diagnosis.

Probing Depth
Probing depth measurement, after the initial soft tissue healing upon loading, should be
established and monitored over time (Padial-Molina et al. 2014). Human and animal stud-
ies have shown that a soft tissue barrier adjacent to an implant-supported restoration is completely established within 8 weeks (Tomasi et al. 2014; Chrcanovic et al. 2016). Hence, to allow this initial soft tissue healing to occur, according to the Dutch approach, the baseline measurement should be performed around 8 weeks after the prosthesis installation, in order to give the peri-implant mucosa around the restoration the necessary time to mature. Progressive changes in probing depth compared to previous measurements can be an alarming sign. In experimental peri-implantitis studies, an increase in probing depth over time has been associated with clinical attachment and bone loss around implants (Lang et al. 1993; Schou et al. 2004).

Peri-implant tissues are sensitive to probing force variations (Ericsson et al. 1993; Mombelli et al. 1997). In the past, it has also been suggested that probing around implants would damage the soft tissue seal around them. However, Etter and colleagues (2002), in an experimental study, evaluated the healing following standardized peri-implant probing using a force of 0.25 N and observed complete re-establishment of the junctional epithelium within 5 days. The findings of this study clearly imply that peri-implant probing using a probe with a light pressure of 0.25 N will not cause damage to the peri-implant tissues and is recommended for the evaluation of the peri-implant tissue health status. There are no data available whether the material of the probe (metal or plastic) or the probe design can influence peri-implant probing measurements (Heitz-Mayfield, 2008). Empirically, a plastic probe appears more favourable because it is flexible and can follow the bulging contour of the implant-supported restoration more easily.

In contrast to natural teeth, for which average periodontal probing depth has been reported, the physiologic probing depth of the peri-implant sulcus has been a matter of debate (Salvi & Lang 2004). Probing depths around implants can be influenced by different factors such as probing force, thickness of the peri-implant mucosa, placement level and type/design of implant, abutment or restoration (Lang et al. 1994; Salvi & Lang 2004). Generally, probing pocket depths can vary between implant systems, aesthetic placement depths, bone levels to adjacent teeth, healing time, surgical protocol (one or two stages), and loading protocol (Padial-Molina et al. 2014). Platform switching may lead to shallower measurements because the probe tip may stop on the neck of the implant. In the aesthetic zone, where implants are placed deeper for a better emergence profile, probing depths of ≥ 5 may be accepted, if not accompanied by other symptoms or signs of inflammation (e.g. bleeding on probing, suppur-ration, pain or discomfort). However, it must be kept in mind that pockets of ≥ 5 mm repre-
sent niches where anaerobic bacteria can be found (Misch et al. 2008). Regular maintenance is, thus, mandatory to preserve a stable peri-implant condition. Long-term investigations in humans have shown that the probing depth of a healthy peri-implant sulcus is not always < 4 mm but in fact, often > 4 mm and sometimes ≥ 6 mm (Coli et al. 2017). Therefore, single probing depth measurements, solely, should not be considered a diagnostic tool for the presence of disease, but should always be combined with other clinical signs of disease, e.g. bleeding on probing, suppurative, as well as, radiographic evidence of ongoing bone loss. Nevertheless, it should be realized that, at present, peri-implant pocket probing provides the clinician with the best information in order to evaluate the condition of the peri-implant soft tissues.

**Bleeding on probing**
Bleeding on gentle probing (≤ 0.25 N) is considered a useful parameter for monitoring the peri-implant mucosal tissue condition and for the diagnosis of mucosal inflammation around implants (Luterbacher et al. 2000). Bleeding on probing (BOP) has a high negative predictive value. In other words, absence of BOP is a good indicator of a stable peri-implant condition (Jepsen et al. 1996). Bleeding upon gentle probing (≤ 0.25 N) is considered a key parameter for the diagnosis of peri-implant mucositis (Lang & Berglundh 2011). However, it should be kept in mind that stable peri-implant sites, in some cases, also slightly bleed on probing which may be the result of disrupting the epithelial junction.

**Suppuration**
The presence of pus indicates the presence of inflammation. Pus is frequently associated with progressive bone loss and peri-implantitis (Roos-Jansåker et al. 2006; Fransson et al. 2008) and is a common finding in peri-implantitis sites (Lang & Berglundh 2011).

**Prevention**
The key for the long-term success of implants is prevention of peri-implant diseases based on proper implant design, proper placement and correct contours for ease of oral hygiene, along with meticulous maintenance care by both the dental care professional and the patient (Tarnow, 2016). Attendance to a regular supportive periodontal therapy program (SPT) has been found to be strongly related to implant survival (Anner et al. 2010) and reduces the risk
for the development of peri-implant disease, especially in subjects affected by periodontitis (Roccuzzo et al. 2012).

During SPT, an update of the medical and dental history, a thorough examination of the peri-implant and periodontal tissues and an inspection of the implant-supported restoration should be performed (Heitz-Mayfield et al. 2014). The level of patient’s self-performed oral hygiene should also be evaluated. Examination of the peri-implant tissues should include assessment of the presence of plaque, probing pocket depth, presence and severity of bleeding on gentle probing and/or suppuration. The colour and tonus of the peri-implant mucosa should also be evaluated. The probing depth measurements should be compared to previous examinations. Progressive changes compared to previous measurements are an alarming sign. When changes in clinical parameters indicate disease, a radiograph should be taken to evaluate possible bone loss compared to previous examinations (Lang & Berglundh 2011). Possible reasons to take a radiograph could be an increase in probing depth of ≥ 2mm compared to previous examination (Roos-Jansåker et al. 2006), which may be accompanied with severe bleeding and/or suppuration; suspected mobility of the implant; or patient’s discomfort/pain.

In every follow-up visit, the frequency of the maintenance should be determined, on the basis of an individual risk analysis, taking into account local and patient-related factors. In every follow-up visit, the recall interval should be revised and, if necessary, adapted.

*Peri-implant health* is defined as the absence of clinical signs of inflammation, absence of radiographic bone changes of more than 2 mm compared to the baseline radiograph after physiologic bone remodelling, absence of pain upon function and absence of mobility (Misch et al. 2008; Heitz-Mayfield et al. 2014). In this case, a recall frequency of twice a year is recommended, precluding that local and/or systemic factors require more frequent intervals (Monje et al. 2016) (Figure 1). Professional cleaning, including reinforcement of the oral hygiene is recommended as a preventive measure (Heitz-Mayfield et al. 2014).

The removal of biofilm from implant components exposed to the oral environment, which have mostly a smooth surface, constitutes an important part of the professional supportive therapy. Ideally, the instruments used to effectively clean smooth surfaces should cause minimal or no surface damage, should not create a surface that is more conducive to bacterial colonization and should not affect the implant–soft tissue interface. If, however, the soft tissue attachment is disrupted, the instrumentation procedure should maintain a surface that is conducive to re-establishment of the soft tissue seal (Louropoulou et al. 2014).
Based on the available *in vitro* data, air-abrasive devices with less abrasive powders and sonic and ultrasonic devices with non-metal tips appear to be effective in removing non-calcified deposits from smooth implant surfaces, without causing noticeable changes on the structure of the implant surface. Summarizing the evidence, air abrasive devices are, at present, the most effective instruments in removing biofilm from smooth surfaces (Louropoulou et al. 2012, 2014). In a six-month randomized clinical trial air-abrasive debridement with glycine powder was compared to manual debridement with plastic curettes and chlorhexidine administration for the maintenance of peri-implant status. The authors concluded that the air-abrasive treatment with glycine powder seems adequate and more effective than manual instrumentation in removing the peri-implant biofilm and in maintaining the health of peri-implant tissues (Lupi et al. 2016).

**Treatment of peri-implant diseases**

*Peri-implant mucositis*

Peri-implant mucositis is defined as the presence of inflammation in the mucosa, evident by bleeding on probing, with or without deepening of the peri-implant pocket and without radiographic evidence of bone loss compared to the baseline radiograph. In general, peri-implant mucositis can be managed with nonsurgical treatment. However, current data indicate that complete resolution of the inflammation, as evident by absence of bleeding on probing, is not always possible (Jepsen et al. 2015). Improvement of the oral hygiene of the patients and professionally-administered mechanical cleaning of the implant components, employing different hand or powered instruments with or without air-abrasive devices, should be considered the standard of care for the management of peri-implant mucositis (Jepsen et al. 2015) (Figure 1). The adjunctive use of local antiseptics or antibiotics (i.e. local and systemic) does not seem to improve the efficacy of mechanical plaque removal in improving the clinical parameters in mucositis sites (Schwarz et al. 2015; Salvi et al. 2015).

Sometimes, iatrogenic factors are present and play an important role in the initiation of peri-implant mucositis. Removal of these factors is mandatory in order to achieve improvement. Cement remnants, if present, should be removed and prosthodontic issues like inadequate abutment/restoration seating or over-contoured restorations should be corrected. In case of implant mal-positioning, surgical correction of the hard and soft tissues may be necessary to reduce the inflammation and to improve the accessibility for proper oral hygiene (Figure 1).
After treatment, enrolment in a maintenance program is necessary to maintain a stable peri-implant condition. The absence of maintenance in individuals treated for peri-implant mucositis has been associated with a higher risk for developing peri-implantitis (Costa et al. 2012).

**Peri-implantitis**

Peri-implantitis is defined as the presence of changes in the level of crestal bone over time, accompanied by bleeding on probing and/or suppuration with or without concomitant deepening of the peri-implant pocket (Lang & Berglundh 2011). Sometimes, these symptoms are accompanied by redness and swelling of the peri-implant mucosa and patient’s symptoms like discomfort or pain.

When peri-implantitis is diagnosed, proper treatment should be started, as soon as possible (Figure 1). The ideal goal of the treatment would be the resolution of inflammation with no suppuration or bleeding on probing, no further bone loss, and the reestablishment and maintenance of healthy peri-implant tissues (Heitz-Mayfield et al. 2014). “A composite outcome of disease resolution including the absence of deep pocket depth with bleeding and suppuration” can be considered (Sanz & Chapple 2015). However, peri-implant pocket depth can be influenced by different factors, as discussed above, and, therefore, the classification of a “deep” pocket needs to be done on an individual basis (Schwarz et al. 2015).

The treatment of peri-implantitis starts with a nonsurgical therapy, consisting of improvement of the oral hygiene of the patient and professional cleaning of the infected implant components (Figure 1). Any co-existing periodontal disease should also be treated. From the existing literature on nonsurgical therapy of peri-implantitis, it seems that limited clinical improvements can be achieved following mechanical therapy alone using specially designed carbon-fiber curettes, ultrasonic devices and titanium instruments (Renvert & Polyzois 2015). Glycine powder air polishing appears to improve the efficacy of nonsurgical treatment of peri-implantitis. Glycine powder air polishing was associated with a significant improvement in bleeding scores over the control measures investigated (Schwarz et al. 2015a).

A recent systematic review showed that adjunctive local antibiotics/antimicrobials might improve the efficacy of conventional mechanical debridement (Schwarz et al. 2015). Better results regarding bleeding on probing and probing depths, were observed, although
the lesion was not resolved in all cases. From a clinical perspective, this combined therapy
may serve as an alternative therapy when surgical intervention is not possible (Renvert &
Polyzois 2015).

Regarding the use of systemic antibiotics, a number of case series suggest an improve-
ment in clinical parameters (Mombelli & Lang 1992; Khoury & Buchmann 2001). The avail-
able data are very limited and do not allow any definite conclusions, as the studies include
both local and systemic use of antimicrobials/antibiotics (Renvert & Polyzois 2015).

In case of peri-implantitis, nonsurgical treatment is often not sufficient to resolve the
inflammation. This is due to the inaccessibility for proper decontamination of the infected
implant surface. In many cases, a surgical treatment is also necessary (Renvert et al. 2008).
Nevertheless, nonsurgical therapy should always be performed before surgical interven-
tions. A preparatory phase allows the clinician to evaluate the patient’s ability to perform
good oral hygiene. If adequate oral hygiene cannot be obtained, the clinician may consider
other treatment options. It remains however possible that the initial nonsurgical therapy
may resolve the problem (Renvert & Polyzois 2015). A recent study systematically evalu-
ated the effectiveness of nonsurgical therapy for the treatment of peri-implant diseases
including both, mucositis and peri-implantitis lesions. It was concluded that although
nonsurgical treatment for peri-implant mucositis seems to be effective, modest and not-
predictable outcomes are expected for peri-implantitis lesions. Limitations of this study
include different peri-implant diseases definitions, treatment approaches, as well as differ-
ent implant designs/surfaces and defect characteristics (Suárez-López et al. 2016).

The main goal of surgery is to provide better access to the contaminated rough im-
plant surface. Different instruments, including mechanical instruments and chemical
agents, have been used for the decontamination of the infected surfaces. Clinical improve-
ments have been reported for air-abrasive devices or lasers, but the available evidence is
still very weak (Renvert & Polyzois 2015). A retrospective study evaluating the effect of
an air-abrasive device during surgical treatment of peri-implantitis compared with plastic
curettes and cotton pellets impregnated with saline reported that, although both groups
revealed a significant improvement in clinical parameters, the air abrasive group yielded
better improvements regarding bleeding scores and probing depths at 12 months (Toma et
al. 2014). In the surgical treatment of peri-implantitis, chlorhexidine failed to show supe-
rior clinical results compared to placebo-control, although it resulted to a greater suppres-
sion of anaerobic bacteria in short term (De Waal et al. 2013).
If surgery is required, resective or regenerative techniques may be used, depending on the clinical situation. A resective treatment approach may also be combined with surface modification including removal of implant threads. In this study, radiographic assessment of marginal bone levels have shown that implantoplasty combined with resective surgery resulted in significantly better results and a stabilization of the bone level 3 years after surgery compared with resective surgery alone (Romeo et al. 2007).

Serino and Turri (2011) evaluated the outcome of a surgical procedure based on pocket elimination and bone re-contouring combined with plaque control before and after surgery in the treatment of peri-implantitis. Two years after treatment 48% of the patients had no signs of peri-implantitis. However, 42% of the treated implants presented peri-implant disease despite treatment and 7 implants with bone loss ≥ 7 mm had to be removed during the follow-up period. The authors concluded that complete disease resolution seems to be dependent on the initial bone loss at implants and that disease progression was observed for the implants that still showed signs of disease after treatment (Serino & Turri 2011).

Resective techniques are mostly the treatment of choice in the non-aesthetic areas of the mouth. In the aesthetic zone, in which exposed implant threads would be an undesirable complication, other treatment approaches may be required (Renvert & Polyzois 2015). If retentive bone defects are present, open flap debridement and decontamination of the implant surface may be accompanied by regenerative techniques in order to restore the osseous defect (Claffey et al. 2008). A number of grafting materials, with or without barrier membranes, as well as the use of membranes alone, have been advocated over the years, in an attempt to regenerate the lost bone and establish re-osseointegration. Although, an improvement in the clinical parameters has been observed, with pocket depth reduction and radiographic bone fill, failures have also been reported (Renvert & Polyzois 2015). The outcomes of therapy may be influenced by several local factors, mainly including the physicochemical properties of the bone filler, the defect configuration, and the implant surface characteristics (Schwarz et al. 2015). To date, limited evidence is available on the long-term effects of regenerative procedures (Schwarz et al. 2009; Roos-Jansåker et al. 2011). In a 4-year follow-up study of 11 patients, it was concluded that clinical improvements could be maintained after treatment with a xenograft and a collagen membrane (Schwarz et al. 2009). The ability of the patient to maintain good levels of oral hygiene after treatment seems to be a prerequisite for long-term stability (Schwarz et al. 2009; Roos-Jansåker et al. 2011).
A mobile implant should always be removed because there is no chance that osseointegration will occur again. It is important to be sure that the implant itself is mobile and not the prosthetic components. In case of advanced peri-implantitis or persisting peri-implantitis or in case of extreme implant mal-positioning, removal of the implant should be considered (Figure 1).

After active treatment, enrolment in regular supportive therapy results in the maintenance of stable peri-implant conditions in the majority of patients and implants. However, in some patients recurrence of peri-implantitis may be observed (Heitz-Mayfield et al. 2016).

**Oral Hygiene**

Proper maintenance of implant-supported restorations is to a large extent in the control of the patient and is dependent on his/her daily oral hygiene. Powered toothbrushes seem to be effective in cleaning both fixed and removable implant-supported restorations. However, there is no hard evidence that powered toothbrushing is superior to manual toothbrushing. Nevertheless, powered toothbrushing may help to overcome limitations in manual dexterity and accessibility (Louropoulou et al. 2014).

The evidence on interproximal cleaning around implant-supported restorations is very limited. Interdental brushes, when used by a trained dental professional, seem to be effective in removing plaque from interproximal areas (Chongcharoen et al. 2012). One study reported that using a water jet stream device resulted in greater reduction in bleeding compared to traditional floss (Magnuson et al. 2013). However, the lack of controlled clinical trials makes it difficult to draw any firm conclusions on their relative effectiveness. Chemical agents have also been tested in combination with mechanical plaque control. However, the data on the adjunctive effect of these agents is not conclusive (Salvi et al. 2015).

Self-performed home care around implants is, at present, mainly based on the knowledge that is available from the periodontal literature, with respect to cleaning of natural teeth. Individually tailored oral hygiene instructions should be given to patients rehabilitated with dental implants. The design of the implant-supported restorations should also allow accessibility for proper oral hygiene at the implants. Otherwise, the restorations should be adapted or replaced by cleansable restorations (Salvi et al. 2015).
Conclusions

Good oral hygiene and regular maintenance are key factors for long-term success with dental implants. Baseline clinical and radiographic recordings are necessary for the long-term follow-up of implants. Regular monitoring of the peri-implant tissues includes assessment of the peri-implant probing depth, bleeding on gentle probing and/or presence of suppuration. If necessary, based on the clinical findings, the bone level should be evaluated. A single measurement of one factor cannot be used to differentiate health from disease. Changes over time, compared to previous recordings, can be an alarming sign.

If disease is diagnosed, treatment should be initiated, as soon as possible. The treatment consists of reinforcement of the oral hygiene and nonsurgical therapy for the decontamination of the implant surface, followed if necessary by surgery. Local antimicrobials/antibiotics may be used as adjunct in the nonsurgical treatment of peri-implantitis.

The treatment of peri-implant mucositis is considered to be predictable. However, it should be kept in mind that complete resolution of the inflammation is not always possible and that some implants will remain to present with bleeding on probing after treatment. Supportive therapy is necessary to maintain a stable peri-implant condition and to reduce the risk for relapse. The treatment of peri-implantitis is not always predictable and may sometimes include removal of the infected implant.

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Declaration of interest

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Authors’ contributions

A. Louropoulou contributed to the conception, design, acquisition, analysis, interpretation of data, drafted the manuscript.

G.A. van der Weijden contributed to the conception, design, analysis, interpretation of data, critically revised the manuscript for important intellectual content.
All authors gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
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Table 1. Parameters that should be evaluated during baseline clinical assessment. Similar assessments should be done in any subsequent evaluation.

Baseline assessment around 8 weeks after placement of the implant-supported restoration:

- Assess pocket depth
- Assess bleeding on gentle probing
- 1st radiograph (if not already taken immediately after placement of the implant-supported restoration)
- Clinical photograph
- Exudate/Suppuration
- Implant mobility
- Cleansability
- Control Occlusion
Figure 1. Flow chart for the treatment of peri-implant diseases adapted from the Dutch clinical guideline.

Decision tree in the treatment of peri implantitis