Prevention and treatment of peri-implant diseases

Cleaning of titanium dental implant surfaces

Louropoulou, A.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
Titanium implant surfaces

The implant construction that supports the intra-oral restoration consists of two components with distinctive surfaces: the abutment or transmucosal part, which is exposed to the oral cavity and has a smooth surface and the implant itself or implant body, which is the part inserted into the bone and most frequently has a rough surface.

During the first twenty years the implant market was dominated by two implant systems with two discrete surfaces: the machined implant introduced by Brånemark and the titanium plasma sprayed implants introduced by Schroeder (Buser et al. 2017). Nowadays, dental implants are available in different materials, sizes, and lengths and with different surface properties and coatings (Esposito et al. 2014). The currently available implant systems from the major implant manufacturers differ from their respective predecessors in microroughness, physicochemical properties and nanoroughness (Wennerberg & Albrektsson 2010).

The original Brånemark implant had a turned surface. These surfaces are those produced by the turning machine process of a titanium rod and are considered to be smooth surfaces (Wennerberg & Albrektsson 2009). Machined surfaces span a wide range of surface textures (Stout et al. 1990). In implant dentistry the term ‘machined’ is mostly used to describe turned, milled or polished surfaces (Wennerberg & Albrektsson 2009). Implant surface modifications have led to improved bone-to-implant contact and better and stronger bone responses. They have allowed for reduced healing periods and predictable treatment outcomes in numerous treatment indications, such as immediate placement and immediate loading (De Bruyn et al. 2017). The modification methods can be divided into subtractive and additive processes. The subtractive techniques remove material from the implant surface creating pits or pores on the surface and result in a concave profile. Examples for these techniques are electropolishing, mechanical polishing, blasting, etching and oxidation. The additive techniques add material and create a surface with bumps and a convex profile. Examples of these techniques are hydroxylapatite and other calcium phosphate coatings, titanium plasma spraying and ion deposition (Wennerberg & Albrektsson 2009).

Surface roughness is often described in terms of Ra, a two-dimensional measurement, or preferably Sa, the corresponding three-dimensional parameter. These parameters describe the height of a surface structure, i.e. the average mean deviation of a profile (Ra) or surface (Sa) (Wennerberg & Albrektsson 2009). According to their surface roughness, dental implant surfaces are classified into four different groups. Smooth implant surfaces refer to a Sa value...
of less than 0.5 μm; minimally rough surfaces refer to Sa values of 0.5 to less than 1.0 μm; moderately rough surfaces refer to Sa values between 1.0–2.0 μm; and rough surfaces have an Sa value of more than 2.0 μm (Albrektsson & Wennnerberg 2004). Currently, minimally and moderate rough surfaces are accepted as the preferred surfaces for the part of the implant inserted into the bone (Wennnerberg & Albrektsson, 2010; Buser et al. 2017).

On all implant surfaces a biofilm can form. However, surface properties may influence its formation. The roughness of the implant surface, as well as its chemical composition and surface free energy, has an impact on the amount and quality of plaque formation. Rougher surfaces and surfaces with high free energy, which is a characteristic of titanium, accumulate and retain more plaque. The initial adhesion of bacteria starts at locations with high wettability, which is also a characteristic of titanium, and from surface irregularities, like pits and grooves, where bacteria are protected from shear forces (Teughels et al. 2006). Consequently implant surfaces have been found to accumulate more plaque than natural teeth (Quirynen & Bollen 1995), and roughened titanium surfaces are considered to accumulate and retain more plaque than smooth surfaces (Quirynen et al. 1993). A Ra value of \( \approx 0.2 \mu m \) has been suggested as a threshold roughness value below which no further significant changes in the amount of adhering bacteria can be observed (Bollen & Quirynen 1997).

Surface roughness also influences the quality of the soft tissue seal. The surface of a transmucosal abutment should be smooth to establish a long-lasting soft tissue seal and to avoid adverse soft tissue reactions (Sawase et al. 2000). Nevertheless a certain surface roughness is required for an optimal soft tissue seal. Highly polished abutments favour less plaque retention but they have been found to negatively affect the soft tissue seal due to interactions between surface structure and fibroblast and/or epithelial cell attachment and proliferation (Bollen et al. 1996). Thus implant components exposed to the oral cavity should have a smooth surface to avoid plaque accumulation and to promote an optimal soft tissue seal. The Ra values of the transmucosal part of most implant systems, nowadays, range from 0.1 to 0.3 μm, which is within the range of a smooth enamel surface and/or polished restorative materials (Quirynen et al. 1994a). Yet, because of the limited hardness of titanium there is, in theory, a risk of surface roughening during self-performed or professional cleaning (Quirynen et al. 2002).

Surface topography can affect the cell shape, orientation, proliferation and function (Könönen et al. 1992). Surface chemical composition is also important for tissue interactions (Sawase et al. 2000). It is generally accepted that the outermost atomic layer of the implant
surface is an essential factor for the interaction with tissues. A major problem associated with the removal of plaque from implant surfaces is the possible damage to the implant surfaces. Any damage to the surface induces changes in the chemical oxide layer (Kasemo & Lausmaa 1988) which in turn may affect the biocompatibility of the implant and consequently impair cell adhesion (Mouhyi et al. 1998). When the surface topography changes also the surface chemistry or physics may change simultaneously. Furthermore, when the surface microtopography is changed, the nanotopography of the same surface usually also changes. All these factors may affect biological responses (Wennerberg & Albrektsson 2009).

**Mechanical instruments**

Prevention of peri-implantitis implies keeping smooth surfaces of the implant supported restoration clean. 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 the soft tissue attachment is disrupted, the instrumentation procedure should maintain a surface that is conducive to re-establishment of the soft tissue seal. When bone is lost, rough surfaces become exposed resulting in the bacterial colonization of these surfaces. The decontamination of these surfaces is mandatory to achieve healing, with re-osseointegration being the ultimate goal (Mombelli, 2002). In order to reduce microbial adherence and colonization on those rough surfaces that remain exposed to the oral environment, removal of the macroscopic and microscopic retentions is suggested (Jovanovic et al. 1993). The effect of mechanical instruments on smooth and rough titanium surfaces with respect to surface alterations, cleaning efficacy and biocompatibility has been evaluated in the studies presented in chapters 2, 3 and 4.

**Surface alterations**

**Chapter 2** scrutinized the available evidence on the effect of instrumentation on the surface roughness. Because of the nature of the question, experimental and mostly in vitro, studies were included in the analysis. Regarding smooth surfaces, a roughening of the surface was observed when these surfaces were treated with metal curettes or sonic and ultrasonic devices with metal tips. Although with titanium curettes this occurs to a lesser extent the use of these instruments on smooth surfaces is not advisable. Similar findings were reported in
an experimental study using a bone defect-simulating model. Scanning electron microscopy (SEM) images revealed significant changes on the morphology of smooth surfaces when metal curettes and ultrasonic devices with metal tips were used (Sahrmann et al. 2015). In contrary, a recent study by Schmidt et al. (2016) reported no changes on the machined surface of an implant neck after a single use of an ultrasonic device with a metal tip, except for a tendency towards a smoother surface compared to the control. The implants were embedded into plastic models, which were then attached to a phantom head. This study setup, the handling of the instruments and the subjective nature of the ranking method used to evaluate changes may account for the observed differences.

A variety of non-metal curettes and inserts for sonic and ultrasonic devices have been developed and tested on smooth titanium surfaces, like plastic, teflon-coated, carbon or polyetheretherketone (PEEK) composite instruments. The use of non-metal instruments does not seem likely to produce a considerable level of surface roughening, although some roughening of the surface can be seen after multiple use. This damage can vary depending on the instrument used. The material of the instrument seems to be an important factor for the amount of the damage seen. When different non-metal instruments and inserts for sonic and ultrasonic devices were tested on titanium discs with polished surface, the least damage was seen with the carbon curette (Schmage et al. 2012).

Rubber cups do not seem to alter a smooth surface. It even seems possible to remove minor scratches and to restore the integrity of surfaces that have been slightly altered as a result of professional instrumentation by using rubber cups with flour of pumice paste or other polishing agents. This is dependent on the abrasiveness of the material.

Air polishing seems to cause no marked surface changes. Yet, some studies reported roughening of the surface. Differences in treatment time, angulation of the tip and distance from the surface may account for the reported differences. In the majority of the studies included in chapter 2, the air-abrasive device was used in combination with a sodium bicarbonate powder, which is rather abrasive. Increased surface roughness with crater formation has been reported when a sodium bicarbonate powder was used on titanium abutment surfaces (Cochis et al. 2013). Nowadays, less abrasive powders like amino acid glycine powders with different particle sizes, tricalcium phosphate powders and an erythritol powder are commercially available. In vitro studies have shown that these powders cause slight no or slight changes on smooth surfaces (Cafiero et al. 2016; Sarhmann et al. 2015; Schmage et al. 2012; Schmidt et al. 2016).
The studies included in chapter 2 evaluated two types of rough surfaces: a moderate rough (SLA) and a rough (TPS) surface. Burs and metal instruments smoothen both surfaces by removing a part of the coating while non-metal instruments cause no visible changes. Air abrasive devices with a sodium bicarbonate powder seem to slightly smoothen SLA surfaces by flattening the sharp-edged elevations. No visible changes were observed on TPS surfaces. Similarly, the application of less abrasive amino acid glycine powders with different particle sizes on SLA surfaces does not seem to cause major changes on the surface roughness. Although sometimes a slight rounding of the sharp edges has been observed (Schwarz et al. 2009; Tastepe et al. 2013; Sahrmann et al. 2015). In general, air abrasive devices do not seem to cause major changes on moderate rough and rough surfaces. The slight changes that can sometimes be observed are dependent on the powder used, the angulation of the tip and the treatment time.

From chapter 2 it becomes obvious that mechanical instruments can have an effect on the various titanium surfaces. Some instruments induce minimal, scarcely visible changes in surface topography while others account for more pronounced changes. The effect of mechanical instruments on the surface structure is dependent on various parameters related to the instrument used, but also to the surface itself. The degree of change that might be inflicted by an instrument is dependent on the material of the instrument, the treatment time and treatment mode (e.g. handling pressure, speed and direction of movement, angulation of the tip, hardness of tips or powders used). It should be kept in mind that what seems as a minor change after a single use may become a major change after repeated application of an instrument on the same surface. This is important for surfaces that are exposed to the oral environment and for instruments that are causing a roughening of the surface, especially since frequent maintenance is recommended for patients having dental implants. Depending on the surface and its localization, the best suitable instrument for this surface should be chosen. From the available instruments the air polisher seems at this moment the most suitable instrument for both smooth and rough surfaces, when preservation of the surface structure is required.

Surface decontamination

The effect of mechanical instruments on the surface structure may be of secondary importance, in case an instrument is not effective in removing accretions from the surface. A successive systematic review was performed in chapter 3 to evaluate the ability of various
mechanical instruments to clean contaminated implant surfaces. Based on the available evidence non-metal curettes were found to be ineffective in removing bacteria and/or bacterial products from both smooth and rough titanium surfaces. Better results have been observed for sonic and ultrasonic devices with non-metal tips. These instruments were more effective in cleaning smooth than rough titanium surfaces. The effectiveness seemed to be dependent on the composition of the tip.

Rotating titanium brushes showed promising results on SLA surfaces. The best results were observed for the air-abrasive devices. These devices, when used with a sodium bicarbonate powder, were found to be effective in removing bacteria and bacterial products for both smooth and rough surfaces. All studies reported more than 84% removal of deposits irrespective of the surface type. Similar results were also observed when the less abrasive amino-acid glycine powders were used. However, complete biofilm removal should not be expected. These results are in agreement with another review on air abrasive devices (Tastepe et al. 2012). The authors of this review reported: “In vitro, the cleaning efficacy of air-powder abrasive treatment on titanium strips, discs or implants is high”. Promising results for the air abrasive were also reported in a review evaluating the decontamination of infected implants by mechanical, chemical and physical methods (Meyle 2012). This review included in vitro, animal and human studies, and the authors concluded: “For decontamination of infected implant surfaces air-abrasive treatment seems to work”.

In clinical situations, several factors, such as the soft and hard tissues surrounding the implant, the implant/abutment design or the design of the restoration may render the accessibility of the titanium surfaces more difficult and may limit the cleaning efficacy of an instrument. The accessibility of an air abrasive device with glycine powder to clean minimally rough implant surfaces was assessed in models imitating peri-implantitis with different defect morphologies. The authors concluded: “Although a complete cleaning of the implant surfaces was not possible in any of the defect models, it was possible to clean the biggest part of the surface up to more than 95% in easy accessible defects. In broad defects of 60° and 90° defect angulations, it was even possible to get access to more than 75% of the lower faces of the implant threads”. Narrow defects (< 30°) and the area under the threads were difficult to reach (Sarhmann et al. 2013). In a subsequent study using the same model, the air-abrasive device was compared with other modalities as a stainless-steel curette and an ultrasonic device with metal tip. For implants with a smooth neck and a body with SLA surface the air abrasive device showed a superior cleaning potential as compared to the debridement
with ultrasonic and manual instruments. In wide defects, the differences between the instruments were more pronounced (Sahrmann et al. 2015). The two-abovementioned studies simulated condition similar to an open-flap debridement. Recently, the same research group published another study using a bone defect-model that includes a custom-made mucosa mask in order to simulate the conditions of nonsurgical implant surface debridement, which made the access to the implant even more difficult. The air abrasive with a glycine powder and a subgingival nozzle provided superior cleaning results compared to a metal curette or an ultrasonic device with a metal tip. Again the differences between the instruments were more pronounced in the wider defects irrespective of the operator’s experience (Ronay et al. 2016). Air pressure seems to be the most important parameter that influences the cleaning efficiency of the air abrasive device. It has been shown that in order to get the best results when used subgingivally the device should be used with high pressure, deep insertion of the nozzle and enough water flow. The cleaning effect of the device reaches deeper than the nozzle physically reaches and the movement of the nozzle improves the cleaning efficiency, irrespective of the direction of the movement (Tastepe et al. 2016).

**Surface biocompatibility**

Bacterial contamination has been shown to affect cell behaviours and to alter the elemental composition of a titanium surface. Kawahara et al. (1998a, 1998b) investigated cell contact to titanium surfaces and adhesive strength of epithelial cells and fibroblasts in the presence of plaque extracts. The plaque extracts had a greater effect in decreasing the growth rate of fibroblasts than that of epithelial cells. Mouhyi et al. (2000) indicated that biofilm increases the amount of carbon (C) at the titanium oxide layer. The elemental composition of unused commercially pure titanium foils was 9% titanium (Ti), 48% carbon (C), 40% oxygen (O) and traces of 10% nitrogen (N) and chlorine, whereas intraorally contaminated foils exhibited 70% C, 20% O, 10% N and only traces of titanium (<1%). Next to bacterial contamination, treatment modalities used to decontaminate the titanium surface can also affect its surface topography and chemical composition. The surface composition of failed and retrieved machined titanium implants after various cleaning procedures has been evaluated in a study. Although some of the tested methods resulted in a macroscopically clean surface, all of them failed to re-establish the original surface elemental composition (Mouhyi et al. 1998). In addition, residues of the instruments may deposit themselves to the treated surfaces, which in turn might disturb cell attachment (Schwarz et al. 2003). Residues of various curettes and
inserts for ultrasonic devices, as well as powder remnants after the use of air abrasive devices, have been found on the titanium surfaces after instrumentation (Schwarz et al. 2003; Schwarz et al. 2009; Tastepe et al. 2013).

Alterations to the titanium surface due to contamination and/or after instrumentation may affect biological responses. It is obvious that an instrument would be of no value if it renders the surface non-biocompatible, i.e. intervene with the normal tissue healing. Subsequently a third systematic review was conducted in chapter 4 and concluded that all instruments reduce the biocompatibility of the surface irrespective of the presence or absence of plaque. However, none of them has a deleterious effect.

The air-abrasive devices seem to have the least effect on the biocompatibility. This is based mainly on studies on rough (SLA and TPS) titanium surfaces and with the utilization of sodium bicarbonate powder. This conclusion is in accordance with a recently published study that evaluated the biocompatibility of SLA surfaces after treatment with a plastic curette, an air abrasive device with glycine powder, a titanium brush or implantoplasty (Toma et al. 2016). No treatment modality did impede the biocompatibility of the titanium surface. The air abrasive device showed slightly better results that the other modalities. This study has also reported promising results for the use of implantoplasty on SLA surfaces. This modality induced titanium alloy purity and hydrophily without altering osteoblast proliferation and production of cytokines potentials (Toma et al. 2016). Another study also reported that implantoplasty applied on SLA surfaces was associated with an undisturbed viability of gingival fibroblasts and an elemental composition comparable to machined surfaces, and caused minimal reduction of the implant diameter (Schwarz et al. 2016). Similarly, an earlier animal study employing the ligature-induced peri-implantitis defect model demonstrated the creation of a smooth surface, which supported a close adhesion of the sub-epithelial connective tissue (Schwarz et al. 2011).

Taking together the results of the systematic reviews in chapters 2, 3, 4 it seems, based on the currently available in vitro data, that air-abrasive devices represent the most promising tool in the treatment of peri-implant infections. They are effective in biofilm removal, without causing major changes on the surface topography or having detrimental effect on the biocompatibility of a titanium surface. These results are corroborated to a certain extent by findings from animal studies. Mechanical cleaning with an air abrasive device appeared to provide adequate decontamination to allow for some new bone formation in direct contact with the implant surface (Roos-Jansåker et al. 2003).
A number of clinical studies have also evaluated the efficacy of air polishing compared with other treatments on changing signs of inflammation in patients with peri-implant mucositis or peri-implantitis. These studies have been summarized in a recently published systematic review. The available data suggest that air polishing used as an adjunctive measure or as monotherapy can result in significant clinical improvements in terms of bleeding scores, following a single or repeated nonsurgical treatment of peri-implant mucositis and/or peri-implantitis. At mucositis sites, glycine air polishing seems to be as effective as conventional mechanical debridement with non-metal instruments with or without local antiseptics. For the non-surgical 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. 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 results regarding bleeding scores and probing depths at 12 months (Toma et al. 2014).

**Air abrasive powders**

The type of the powder seems to be of importance for the biological responses. Glycine powders seem to reduce the biocompatibility more than sodium bicarbonate, when used on SLA surfaces (Schwarz et al. 2009). It has been shown that tricalcium phosphate, when used as an additive to powders, may increase the cleaning efficiency of the air abrasive (Tastepe et al. 2013). These results are also supported by the findings from another study that evaluated the effectiveness of a powder consisting of glycine and tricalcium phosphate, in comparison to two established powders based on glycine and sodium bicarbonate, in biofilm removal from SLA titanium surfaces (John et al. 2016). However, all powders that were tested affected the biocompatibility and the extent to which this was influenced depended on the powder used. The less abrasive powders (glycine and glycine with tricalcium phosphate) reduced the viability of SAOS-2 cells more than sodium bicarbonate; but the observed differences were not statistically significant (John et al. 2016). This finding has been attributed to the hardness and bigger particle size of sodium bicarbonate, which has also been observed to induce surface changes. It was speculated that a certain amount of surface ablation might improve the biocompatibility of moderate rough surfaces (Schwarz et al. 2009).
Another possible explanation for the reduced biocompatibility that has been reported in the literature is small particles of the powders embedded at the implant surface (Tastepe et al. 2013). What can be the possible effect of these remnants is not clear yet. In the study in chapter 5, the aim was therefore to assess the possible effect of five commercially available air-abrasive powders, on the viability and cell density of three types of cells: epithelial cells, gingival fibroblasts and periodontal ligament fibroblasts. This study showed that powders might indeed have different effects on various cells. The use of tricalcium phosphate containing powder seems promising. It has been speculated that tricalcium phosphate residues on the implant surface could improve biocompatibility and support wound healing (Tastepe et al. 2013; John et al. 2016). The results of chapter 5 seem to support this notion. However, more studies are necessary in this area.

Chemotherapeutica

Surface decontamination

Chemotherapeutic agents, alone or in combination with mechanical instruments, have also been used for cleaning implant surfaces. Chapter 6 reviewed the literature for evidence regarding the ability of different chemotherapeutic agents to decontaminate titanium surfaces. The available data were very limited and precluded any firm conclusions. Yet, it seems that citric acid has the highest potential to remove bacteria and bacterial products from titanium surfaces. It should however be kept in mind that chemical agents are less capable in removing biofilm than mechanical instruments. In an in vitro study evaluating the effectiveness of different products with chemotherapeutic agents (EDTA, citric acid, cetylpyridium chloride, Ardox-X, hydrogen peroxide, chlorhexidine) to decontaminate machined and SLA titanium surfaces, citric acid showed the highest decontamination potential with respect to both killing and removing bacteria (Ntrouka et al. 2011). These results are to a certain extent corroborated by the findings of another study that evaluated the ability of three chemical agents, citric acid, chlorhexidine and EDTA/sodium hypochlorite, to decontaminate rough implant surfaces contaminated with biofilm grown from in-vivo peri-implantitis sites. The antimicrobial effect was greater for citric acid and EDTA/sodium hypochlorite groups, followed by the chlorhexidine group (Kotsakis et al. 2016). In an earlier study different results with respect to the killing potential of citric acid were reported. In this study the antibacterial efficacy of several antimicrobials on the oral microflora attached to titanium specimens
with a machined surface after overnight contamination in the oral cavity of volunteers was assessed. All agents used were shown to significantly reduce the total number of attached bacteria after immersion for 1 minute. However, citric acid showed less bactericidal effect compared to the other agents. It was concluded that the antiseptics sodium hypochlorite, hydrogen peroxide, citric acid, chlorhexidine, and essential oils might have some beneficial effect in reducing the bacteria load on titanium surfaces (Gosau et al. 2010).

**Surface biocompatibility**

Chemotherapeutic agents may have an effect on the elemental composition of the titanium surface, which subsequently may affect the biocompatibility of the surface and the biologic responses. Elemental contaminants or salts have been found on titanium surfaces after treatment with chemical agents (Mouhyi et al. 1998; Kotsakis et al. 2016). An *in vitro* study assessed the effect of different chemical agents (citric acid, hydrogen peroxide, chlorhexidine, tetracycline, doxycycline, sodium fluoride and peroxyacetic acid) on the oxide layer morphology of titanium. The treatments consisted of immersion of samples in a solution or rubbing them on with cotton swabs. Rubbing with swabs led to signs of titanium oxide damage in a pH-related manner (Wheelis et al. 2016).

One study investigated the attachment and proliferation of epithelial cells on smooth titanium surfaces treated with citric acid, hydrogen peroxide and chlorhexidine. Treatment with citric acid and hydrogen peroxide resulted in respectively similar or enhanced proliferation of epithelial cells compared to an untreated control. Less favourable results were observed with chlorhexidine due to adsorption on the titanium surface (Ugvári et al. 2010). It is also reported that chlorhexidine significantly impaired the proliferation of osteoblasts on treated titanium surfaces. Based on these findings the use of chlorhexidine is not recommended because it produces cytotoxic effects and may thus compromise the biocompatibility of the surface (Kotsakis et al. 2016).

A clinical study demonstrated that the application of a 35% phosphoric etching gel at pH 1 adjunctive to the use of carbon curette and rubber cup resulted at 5 months in a higher reduction in gingival index scores and a lower number of colony-forming units compared to control treatment (Strooker et al. 1998). In patients with peri-implant mucositis, professionally administered chlorhexidine (irrigation, gel application or combination of both) failed to show adjunctive beneficial effects compared with mechanical debridement alone (Porras et al. 2002; Heitz-Mayfield et al. 2011). Similarly, in the surgical treatment of peri-implantitis
chlorhexidine resulted to a greater suppression of anaerobic bacteria in short term but failed to show superior clinical results compared to placebo-control (De Waal et al. 2013).

**Self-performed mechanical home care**

Proper maintenance of implant-supported restorations is to a large extent in the control of the patient and is dependent on the daily oral hygiene. In the study in chapter 7, the available evidence with respect to the patient-administered measures for mechanical plaque removal around implant-supported restorations was scrutinized. Compared to the studies focusing on placing dental implants the scientific literature on how to maintain them is very limited. All studies reported an improvement in the clinical parameters over time. Powered toothbrushes seem to be effective in cleaning both fixed and removable implant-supported restorations. No hard evidence was found that powered toothbrushing is superior to manual toothbrushing, although powered toothbrushing may help to overcome limitations in manual dexterity and accessibility. These findings are in accordance with the recommendations of the Ninth European Workshop on Periodontology regarding patient-administered measures in the management of peri-implant mucositis (Jepsen et al. 2015) and a Cochrane systematic review on interventions aiming at maintaining and recovering soft health around dental implants (Grusovin et al. 2010). The evidence on interproximal cleaning around implant-supported restorations is scarce. Interdental brushes, when used by a trained dental care professional, seem to be effective in removing plaque from interproximal areas (Chongcharoen et al. 2012).

Often implant-supported restorations present contours and shapes that render plaque removal difficult, even by the most capable individuals. A clinical retrospective study showed that high proportions of implants diagnosed with peri-implantitis were associated with inadequate plaque control or lack of accessibility for oral hygiene measures whereas peri-implantitis was rarely diagnosed at implants supporting cleansable restorations or when proper plaque control was performed (Serino & Ström 2009). Like Salvi and Ramseier (2015) stated: “Individually tailored oral hygiene instructions should be given to patients rehabilitated with dental implants. Whenever possible, margins of implant-supported restorations should be placed at or above the mucosal margin to facilitate access for plaque control and implant-supported restorations with poor access for plaque removal should be adjusted or replaced by cleansable restorations”. Anyhow at present, home care recommendations are based mainly on the knowledge that is available with respect to cleaning of natural teeth. It
becomes evident that there is an urgent need for academic institutions and industry to initiate and support high quality randomized controlled clinical trials on this topic in the near future.

**Clinical Guideline**

The consensus report of the Eleventh European Workshop on Periodontology on effective prevention of periodontal and peri-implant diseases stated that primary prevention of peri-implantitis is managing peri-implant mucositis. Consensus was reached on recommendations for patients with dental implants and dental care professionals with regard to the efficacy of measures to prevent or manage peri-implant mucositis. It was particularly emphasized that implant placement and prosthetic reconstructions need to allow proper personal cleaning, proper monitoring of the peri-implant tissues and professional plaque removal (Jepsen et al 2015). Chapter 8 is an epitome of a clinical guideline developed in the Netherlands on behalf of the Dutch Society of Periodontology and the Dutch Society of Oral Implantology regarding the diagnosis, prevention and treatment of peri-implant diseases.

A “Clinical Practice Guideline” (CPG) has been defined as a “systematically developed statement to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances.” (Field & Lohr 1990). Practically, guidelines attempt to distil a large body of medical expertise into a convenient readily usable format (Cook et al. 1997). Briefly, the development of a CPG includes the following five steps: Determination of the scope and the intended audience; Definition of the problem and formulation of focused questions; Search for, selection and combination of the available evidence and evaluation of the quality of the available evidence. This step is done in a way analogous to that used for systematic reviews. The strength of the recommendations is in part dependent on the quality of the available evidence but also on other factors like the balance between desirable and undesirable consequences of specific treatments and cost-effectiveness. Continuous implementation and evaluation of the guideline is mandatory to remain up to date.
Conclusions

Decontamination of an implant surface constitutes an important component in the prevention and treatment of peri-implant diseases. Depending on the surface characteristics, the localization of the surface and the goal of the treatment, the best suitable instrument for each surface should be chosen. Based on the available in vitro data, air abrasive devices with sodium bicarbonate powder appear to be effective in removing biofilm from both smooth and rough titanium surfaces, without causing major changes on the surface structure, especially in the case of rough surfaces. Amino acid glycine powders are less abrasive but seem to be similarly effective in removing biofilm. Newly developed powders, like powders containing tricalcium phosphate and an erytritol powder, seem also effective in removing biofilm from implant surfaces. For rough surfaces that are going to become exposed to the oral environment after treatment implantoplasty seems to be a realistic option if the surfaces is sufficiently accessible. All mechanical instruments affect the biocompatibility of the treated surfaces but none of them seem to have a deleterious effect. The best results have been reported for the air abrasive devices. The selection of the powders seems to be of importance. Powders with tricalcium phosphate as additive may have a beneficial effect on the biological responses.

From the available chemotherapeutic agents, citric acid and hydrogen peroxide seem to have the best potential.

There is much discussion on the aetiology, prevalence and treatment modalities for peri-implantitis, but everybody agrees on one thing; regular controls and meticulous maintenance from both the patients and dental care professionals are mandatory to avoid problems. Baseline clinical and radiographic recordings are important to be able to follow implants over time and to differentiate between health and disease. According to the “Dutch approach”, the first time to assess probing pocket depths around implants should be around 8 weeks after prosthetic installation in order to give the soft tissue the necessary time to adapt. Changes in clinical and/or radiographic parameters can be an alarming sign.

Proper maintenance of the peri-implant soft tissue health is largely in the control of the patient and is depended on the daily self-care. Patients with dental implants should receive individually tailored instructions for optimal oral hygiene. The current home care recommendations are based on the knowledge that is available with respect to cleaning of natural teeth. Subsequently oral hygiene around dental implants should be one of the priorities on the research agenda in dentistry.

Prevention and early diagnosis of problems is the key for long-term success with dental implants. Like Garber already in 1991 stated:

“Implants; the name of the game is still maintenance”.
References


Jepsen S, Berglundh T, Genco RJ, Aass AM, Demirel


Quirynen M, Bollen CML, Willems G, van Steenberghe...


Recommendations on the clinical application of air polishing for the management of peri-implant mucositis and peri-implantitis. *Quintessence International* 47: 293-296.


