Patient compliance as a risk factor for the outcome of implant treatment.

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Abstract
Peri-implantitis can be explained with a multi-causality model. Many factors are involved in the aetiology of peri-implantitis, however the patient compliance also plays a key-role. Oral hygiene, attending recall-visits, smoking behavior and therapy comprehension of patients are indeed relevant factors that contribute to peri-implant health. The clinician should create the most optimal conditions for the patients to facilitate adequate oral self-care and help the patient to improve their oral hygiene skills. The implementation of a Supportive Periodontal Therapy program is mandatory in controlling plaque accumulation and inflammation as well as in keeping the incidence of peri-implant diseases low. Patient's compliance including plaque control and dental follow-up has to be optimal. Consequently, the inclusion of patients treated with dental implants has to be with large precaution.

Introduction

It is well established that maintenance of healthy tissues around implants is one of the key factors for the long-term success of implants. Plaque accumulation induces an inflammatory process that may lead to a progressive destruction of soft and hard tissues and ultimately to implant failure.[1–3] The inflammatory process, described as mucositis, like gingivitis around natural teeth, is a marginal inflammation without attachment or bone loss.[4] The inflammatory process associated with loss of marginal supporting bone around an implant in function is defined as peri-implantitis.[5,6]

A problem with the diagnosis of peri-implant diseases is that depending on the used diagnostic criteria, a substantial variance in prevalence has been reported in the same patient population.[7] The current guidelines for the definition and diagnosis of peri-implant diseases have been established in the 6th, 7th and 8th European Workshop on Periodontology.[6,8,9] The prevalence of peri-implantitis seems to be in the order of 10% at implant level and 20% at patient level during 5–10 years of function.[10] A meta-analysis reported a weighted mean prevalence of peri-implant mucositis of 43% (1196 patients and 4209 implants) and a weighted mean prevalence of peri-implantitis of 22% (2131 patients and 8893 implants). However, the authors stated that the heterogeneity in definition criteria of peri-implantitis could be a confounder.

Peri-implantitis has been primarily described as a simple infectious pathological condition of peri-implant tissues.[1,11] Later, many local factors such as implant surface, topology and bacterial contamination at the implant/abutment junction and patient factors such as smoking habit, poor oral hygiene, history or presence of periodontitis, genetics and excessive alcohol consumption have been associated with an increased risk to develop peri-implant diseases.[12–16]

The aetiology of alveolar bone loss (ABL) around implants plays a crucial role in the classification of the disease. The most used theories to explain ABL are the infection and overloading theories.[17] The infection theory defines that implants are susceptible to similar types of diseases as teeth, the major difference being the term periodontitis reserved for teeth and peri-implantitis being reserved for implants. The overload theory is not clearly determined, some studies have suggested that overload may play a role when associated with plaque accumulation or pre-existing inflammation.[18] Next to these two, a third theory has been developed where ABL is explained by the synergy of combined factors, such as surgical procedures, prosthodontics and patient disorders.[17] Following this theory, a differentiation between primary and secondary peri-implantitis has been presented. Primary peri-implantitis is diagnosed when the bacterial infection is the primary cause for ABL, while secondary peri-implantitis may originate from other factors.[19] In a recent review, the risk indicators that can lead to peri-implant infection and consequently to secondary peri-implantitis were described.[20] Hence, in its totality, peri-implantitis can be explained with a multi-causality model. The following factors have been considered:

1) *Genetics/host predisposition to disease*, specifically the immune response that determines the susceptibility of individuals. The patients that are more prone to develop peri-implant diseases are those with a history of periodontitis, especially aggressive periodontitis.
2) *Life style of the patient*. Oral hygiene is the most crucial factor, but also smoking habits, diet and stress are relevant. Specifically smokers with an insufficient oral hygiene have an increased predisposition to peri-implant diseases.
3) *Environmental factors*. The microbiota associated with peri-implantitis is comprised of perio-pathogenic bacterial species and anaerobiosis of the bacterial species.
4) *Hardware*. The implant and abutment surface roughness has been shown to be relevant in bacterial contamination, with more ABL for rough implant surfaces. Data comparing the connection between implant and abutment shows more ABL for external compared with internal connection. The use of abutments with a smaller diameter than their corresponding implants (platform switch) seem to have benefits in bone stability.
5) *Treatment procedure*. There are several factors that can influence the implant and peri-implant tissues. It has been proven that a frequent abutment dis- and reconnection, the use of augmentation procedures (GBR), the type of restoration, the treatment capacities of the clinician and the cleansability of the peri-implant tissue will significantly influence the ABL.
6) *Hard/soft tissues.* Management of the soft and hard tissues pre-, per- and post implant placement is a relevant factor on crestal bone stability. The influence of gingiva thickness on ABL at abutment connection, the thickness of the buccal bone, bone density and quality, vascularization of the osteotomy, bone compression and early soft tissue perforation have been reported in several papers.
7) *Foreign body.* The presence of foreign bodies, usually cement residues after crown placement, is probably one of the main causes of iatrogenic peri-implantitis.

The clinical and technical abilities are not the only necessary skills of the clinician; communication, education and motivation of patients are just as important. Patients need to be active partners in the prevention and if needed the treatment and management of peri-implant diseases. Communication is essential for successful management, and behavior change of patients is mostly required. Patient understanding and awareness of potential complications is likely to aide prevention of peri- implant diseases.[21] Therefore, patient compliance is one of the key factors for success in implant therapy. There are several factors that can determinate the success of peri-implant plaque control: oral hygiene, attending recall visits, smoking behavior, therapy comprehension and compliance of patients. These aspects are determinants in the prevention of peri-implant diseases.

Oral hygiene

Experimental peri-implant mucositis and peri-implantitis

The relationship between plaque and gingivitis or periodontitis has clearly been proven via the "classical" experimental gingivitis/periodontitis studies.[22–24] These protocols have also been applied to implants.

A similar clinical study, now comparing teeth and implants after 3 weeks of undisturbed plaque accumulation in 20 partially edentulous patients, reported no statistically significant differences in Plaque Index (PI), Gingival Index (GI), Sulcus Bleeding Index, Pocket Probing Depth and Marginal Recession. This indicated that clinically the inflammatory changes were similar both on teeth and implants.[3] Biopsies of peri-implant mucosa and gingiva revealed that, after 3-weeks of undisturbed plaque accumulation, the connective tissue displayed an increased volume of inflammatory cells with again no statistically significantly difference between teeth and implants sites (e.g. size of the inflammatory cell infiltrate, number of several immune cell populations).[4]

In contrast to these data, a comparison between experimental peri-implant mucositis and experimental gingivitis in 15 partially edentulous patients compared the healing sequence for both inflammatory processes. After 3-weeks of undisturbed plaque accumulation both teeth and implants presented significantly increased plaque deposits and gingival inflammation. However, the implant sites showed higher GI compared with tooth sites, indicating that with a similar bacterial challenge a more pronounced inflammatory response occurred at implant sites. After the period of undisturbed plaque accumulation, a 3-week period of optimal plaque control was instituted. Clinically, despite the resumed plaque control, the soft tissue did not yield pre-experimental levels of gingival and peri-implant mucosal health indicating that a longer healing period was needed. Following the 6-week experimental period the GI at implant sites declined significantly less than that at tooth sites. Furthermore, the inflammation-factor matrix-metalloproteinase-8 (MMP-8) in the crevicular fluid was significantly higher around implants. This result indicated that peri-implant soft tissues developed a stronger inflammatory response to experimental plaque accumulation compared with gingival tissues.[25]

Clinical follow up

Although peri-implantitis has a multifactorial aetiology, the microbial challenge is definitely the most important component. As soon as a dental implant is exposed in to the microbe-loaded oral environment, microbial colonization and challenge takes place.[26,27] In case of suboptimal oral hygiene the microbiota of dental plaque adhering to the implant surface will generate a plaque-related inflammatory soft tissue infiltrate.[28] Consequently, the implants are at risk of developing peri-implant diseases. Especially the subgingival biofilm has been described as one of the main aetiological factors for the initiation and maintenance of peri-implant diseases and subsequently ABL.[3,29–32]

A significant dose dependent correlation between peri-implant diseases and inadequate plaque control at implant sites has been reported in several papers (Tab. 1). The association between inadequate plaque control and peri-implant diseases is indeed supported by several studies. A prospective study reported already in the eighties the correlation between oral hygiene and peri-implantitis. 27 subjects were included, 14 with poor and 13 with good oral hygiene. After 15 years a mean bone loss of 1,7mm was measured in the group with poor oral hygiene, while a mean bone loss of 0,7mm was reported in subjects with good oral hygiene.[33]

Another study including 212 partially edentulous non-smoking subjects rehabilitated with dental implants examined the oral hygiene by the full-mouth plaque scores. It showed an overall 64,4% prevalence rate of peri-implant mucositis and a 8,9% prevalence rate of peri-implantitis. Plaque scores were significantly dose dependent associated with peri-implant diseases, and a very poor oral hygiene was highly associated with peri-implantitis. While peri-implantitis was a rare finding around implants with proper plaque control, a very poor oral hygiene was reported to be a risk factor for peri-implant diseases with an odds ratio (OR) of 14.3.[30]

In contrast, a cross-sectional study observing the risk factors associated with peri-implant lesions, showed a significant association between plaque and mucositis on the implant level. However, no significant association between oral hygiene and peri-implantitis was reported.[34] The absence of a significant association between oral hygiene and peri-implantitis in this study might be explained by the cross-sectional design of the study and the time needed to develop peri-implant diseases.

Therefore, proper oral hygiene measurements are crucial in patients rehabilitated with dental implants.[12,20,35] It is essential to create the most optimal conditions for the patients, in order to perform adequate oral self-care and to help them to improve their skills.

Cleansability (Tab. 2)

It is thus important not only to instruct the patient in his daily oral hygiene routine, but also to follow surgically and prosthetic precautions before insertion of a dental implant.[36] There are indeed several factors, which may compromise cleansability (Tab. 3):

- The presence of a circumferentially band of keratinized mucosa around implants can be of influence for peri-implant health. The influence of keratinized mucosa width on plaque accumulation has been observed in several studies. They clearly demonstrated that a narrow keratinized mucosa (<2mm) was associated with higher plaque accumulation around implants (Fig. 1), especially in posterior regions.[15,37–40]
- Implant surfaces exposed to bacterial contamination, may render oral hygiene with conventional means extremely difficult.[41]
- Several implants next to each other can impair the cleansability, especially when placed in close proximity. (Fig 2).
- A narrow proximity of the implant with the neighboring teeth may also make interproximal cleaning difficult if not impossible (Fig. 3).
- When a wrong positioning and/or angulation of the implants has to be compensated, it may lead to unfavorable constructions with abrupt emergence profile that are impossible to clean.[42]

From a prosthetic point of view, it is essential to provide suprastructures with a design that permits the patients to self-perform adequate oral hygiene. Even the choice of prosthetic construction has an important impact on the cleansability of the peri-implant tissue.

Full fixed prostheses

An increased risk of 16.1 times for peri-implantitis has been reported for total rehabilitations with implants compared to single crown rehabilitations.[43] Problems with cleansability are especially reported for extensive fixed constructions.[44]

The location of the restoration margin is also significant. Implants with supra-mucosal restoration margins showed significantly greater reductions in probing depth following treatment of mucositis compared with those with sub-mucosal restoration margins.[45] Especially when cemented implant restorations are selected, the restoration margins should be located at the mucosal margin to allow meticulous removal of excess cement. The correct fit of implant components and the supra-structure has to be ensured to avoid additional niches for biofilm adherence (Fig. 4).[46] It should also be considered to avoid construction with over-contoured and bulky crowns (Fig. 5).[47] The latter often occurs unfortunately after a wrong positioning of the implants that has to be compensated with over-contoured suprastructures.

Furthermore, one should avoid fixed constructions with too extensive cantilevers or limited embrasure spacing between implants (Fig. 6). These designs promote plaque accumulation by retention and it is extremely difficult for the patient to clean properly.

Overdenture

A bar construction for an overdenture can increase the susceptibility to peri-implantitis by retention of plaque (Fig. 7). On average, an overdenture with milled bars exhibits a higher plaque index, especially in case of a massive one-piece milled bar, when compared to an overdenture retained by telescopic crowns (Fig. 8), resulting in a higher peri-implantitis frequency.[48,49] This can be a problem especially when the bar is positioned too close to the gingiva, impeding proper oral hygiene. However, when the bar design allows to clean the peri-implant tissue, similar parameters between ball and bar anchorage were reported.[50,51]

Elderly patients

Caution should be taken when implants are placed in elderly patients who have been edentulous for several years. They may have forgotten the plaque control techniques. Therefore, it is advisable to reinstruct them in self-performed oral hygiene procedures.[52] Moreover, they often have impaired manual skills and reduced visual capacity. Patients that have been edentulous for many years often display advanced bone resorption. Therefore, implants have to be placed deeper in the oral vestibule, which in turn may compromise the possibilities for adequate plaque control by conventional oral hygiene means. In such a case, for example, the patient has to be instructed to retract the lip, while brushing, to permit direct access to the peri-implant tissue.

Sometimes a conventional removable solution should be proposed, especially for the upper jaw. Several studies reported that mandibular two-implant overdenture opposed by a maxillary conventional denture is a more satisfactory treatment and provide better function and oral health-related quality of life than conventional dentures.[53,54] Furthermore, it is advisable to avoid fixed prostheses when the patient is not able to achieve acceptable oral hygiene standards. Removable long-bar overdentures proved to provide significantly higher ratings of general satisfaction than fixed prostheses. Patients also rated their ability to speak and ease of cleaning significantly better with the removable overdentures.[55]

A study done in partially edentulous patients clearly correlated accessibility for oral hygiene at implants sites and the presence or absence of peri-implantitis. The authors reported that 74% of the implants had no accessibility to proper oral hygiene. 48% of the implants affected by peri-implantitis were those with no accessibility for proper oral hygiene, while accessibility was rarely associated with peri-implantitis.[35]

Candida

When analyzing the importance of compliance and oral hygiene it is relevant to remember the role of fungi, like candida. Candida species can be found in humans as commensal yeasts. In the oral cavity the buccal mucosa is the most important reservoir. In humans wearing a denture, the denture may favor the colonization of the oral cavity by candida. Furthermore, these species can be found in subgingival biofilm were they can co-aggregate with bacteria and adhere to epithelial cells.

The role of *Candida albicans* in peri-implantitis has been investigated in vitro, examining the virulence of candida species in mixed-species biofilms on titanium. *C. albicans* biofilms containing Streptococci showed a significant up-regulation of different virulence factors (ALS3, HWP1, SAP2, SAP6) and increased hyphal production compared with *C. albicans* biofilms alone. Biofilm containing *C. albicans* and *Porphyromonas gingivalis* showed a down-regulation of some virulence genes and hyphal production was decreased. In contrast a mixed biofilm containing *C. albicans*, streptococci and *P. gingivalis* showed up-regulation of ALS3, SAP2 and SAP6. This mixed biofilm was also characterized by an increased hyphal production. Depending on the associated bacterial species this in-vitro study showed that in more complex microbial biofilms still hyphal development and up-regulation of putative virulence factors can occur.[56]

Another in-vitro study tested the effect of several peri-implantitis antiseptics on mono-species biofilms on titanium surfaces. Regarding the *C. albicans* biofilm, sodium hypochlorite, hydrogen peroxide, chlorhexidine and essential oils showed an antifungal activity. This could not been found for citric acid and triclosan. Furthermore, the authors concluded that only sodium hypochlorite was effective on all three tested microbes (*C. albicans*, *Streptococcus sanguinis* and *Staphylococcus epidermidis*).[57]

A systematic review investigated the effect of oral health on candida in hospitalized and medically compromised patients. The authors could not determine an optimal protocol against yeasts. Different interventions were investigated. Chlorhexidine as adjuvants to mechanical oral hygiene had some effect on oral candida, although some studies reported unclear effects. Studies successful at reducing oral candida used chlorhexidine at concentrations of 0.12% or more. In some studies the control group were prescribed Nystatin as an antifungal drug. The equivocal results observed in some studies could be due to the reduced patient compliance and increased antibiotic usage in test groups relative to control groups.[58]

The possible role of candida spp., e.g. *C. albicans*, in biofilm formation and infection should be taken into account during treatment and prevention of peri-implantitis. Further studies are needed to investigate the role of antifungal therapy and which antifungal therapy is most effective on *C. albicans* in peri-implant infections. Furthermore, the high affinity of Candida to dentures should be taken into account. Denture acrylic biofilms contain high numbers of Candida and are frequently linked with tissue damage.

Tooth brushing

The safety and effectiveness of manual, powered and sonic toothbrushes used by patients who have been rehabilitated with implants has been examined in several papers. All three methods did significantly reduced plaque, mucositis and bleeding indices. Some reported that, when comparing to the manual toothbrush, the benefit was greater with the counter-rotational powered or sonic toothbrush.[59,60] An oscillating/rotating powered toothbrush was found to be effective, safe and comfortable for partially or fully edentulous patients rehabilitated with implant-supported fixed prostheses.[61]

Interdental cleaning

To achieve an optimal oral hygiene and healthy peri-implant tissues, also interdental cleaning is crucial. Dental floss and superfloss are usually the most recommended, although some problems have been reported. Ten patients with persistent peri-implantitis revealed, during exploratory surgery, the presence of remnants of dental floss around the exposed rough part of dental implants. After debridement, nine of ten cases resulted in a significant improvement in the peri-implant condition. Afterwards, the application of various types of dental floss on rough implant surfaces has been tested and it has been concluded that this may easily lead to tearing of the floss fibers.[62] These floss fibers, like residual cement in the peri-implant sulcus[63–65], may have acted as ligatures and certainly may lead to the development of plaque-related peri-implant inflammation and, subsequently, bone loss. Consequently, the use of interdental brushes or wooden toothpicks is to be preferred in situations with exposed rough dental implant surfaces.[62]

All these data stress the importance of giving proper oral hygiene instructions to the patients, hand on hand if needed, who are rehabilitated with dental implants and of providing prosthetic constructions with a design that facilitates proper maintenance and allows accessibility for oral hygiene around implants.

Supportive Periodontal Therapy (SPT) and patient compliance

In order to achieve high long-term survival and success rates of dental implants and their restorations, enrolment in regular well-designed SPT including anti-infective preventive measures should be implemented (Tab. 4). Therefore, implant therapy should not be limited to the placement and restoration of dental implants, but complemented with a SPT-program, that stresses excellent oral hygiene.[29,66–73]

Significant differences in the prevalence of peri-implant lesions existed when comparing the long-term outcomes of patients enrolled or not enrolled in SPT (Tab. 5).[31,74] Patients following SPT programs have fewer peri-implant complications.[68,70,72,75–82] Obviously, patient compliance is a crucial factor.[31,35,70]

A retrospective study observed subjects with pre-existing peri-implant mucositis, and compared the peri-implant conditions, five years later. 43,9% of the group without SPT progressed in peri-implantitis while of the group with SPT only 18% progressed in peri-implantitis. These results evidenced that the lack of annual supportive therapy in patients diagnosed with peri-implant mucositis is associated with increased risk for progression from peri-implant mucositis to peri-implantitis.[29]

In a recent systematic review a minimum recall interval of 5 to 6 months depending on the patient's risk profile is recommended. In addition, patients with a higher risk of developing peri-implant diseases due to, for example, a bulky implant supra-structure and systemic or medical factors, such as smoking, should be recalled more often. Although there is no consensus on the interval of SPT.[83]

During SPT several factors have to be examined (Tab. 6): condition of the soft tissues, plaque index, clinical probing depth, bleeding on probing, suppuration, stability of soft-tissue margins, keratinized mucosa, mobility and occlusion. Radiographs should be taken pre-, (intra-) and post-operatively in order to get information about the implantation site and to asses ABL.

Among patients not enrolled in SPT, peri-implant mucositis was reported with a prevalence of 48% over an observation period of 9– 14 years.[31] Especially in patients who lost their teeth because of periodontitis, supportive dental visits reduced the risk of peri-implant diseases. It has been reported that full-mouth plaque and bleeding scores in periodontally healthy or compromised patients rehabilitated with dental implants and adhering to SPT-program, were lower than patients with a history of periodontitis, who did not fully followed a SPT-program. These patients presented a statistically significant higher number of sites that required additional treatment.[80]

The outcomes of a prospective cohort study showed that implants placed in patients treated for periodontitis and enrolled in SPT yielded a low prevalence of peri-implantitis (6%) and of peri-implant mucositis (20%) after 5 years.[84] Hence, it is important, before implant placement, to inform patients of the value of the SPT-program, particularly those affected by periodontitis.

Although different protocols have been proposed for SPT, no consensus is yet available to advise the frequency of recall intervals or to propose a specific protocol for hygiene treatments.[85] However, all the tested procedures reported that the implementation of a systematic hygienic protocol is effective in controlling plaque accumulation as well as in keeping the incidence of peri-implant diseases low.[67,75,86,87]

Compliance

Different studies evaluated the patient compliance rates to SPT programs for "periodontal" patients. The results reported that the compliance often was considered insufficient, particularly with regard to patients treated in private practice.[88–94] Insufficient oral hygiene and poor attendance of the recommended recall appointments after periodontal treatment have been proven to be significantly associated with the progression/recurrence of periodontitis[76,95–99], root caries[100–104] and tooth loss.[105–108]

Obviously, the compliance of the patient rehabilitated with implants is crucial.

Studies on the compliance of patients to SPT after implant treatment are scars. In a 10 years follow-up, 147 patients treated with 2 mandibular implants and overdenture were analysed. They reported that the patient compliance was quite high, with regular recall attendance of >90%. Visits to a dental hygienist and dentist resulted in an annual visit rate of 1.5 and 2.4, respectively.[109]

A retrospective study examined the compliance of 96 patients, determining the impact of active periodontal therapy and the insertion of dental implants. After a 5 years examination period, 77.1% of patients completely complied with SPT while 22.9% of patients had insufficient compliance or dropped out. Interesting is that of the non-compliant patients, 54.5% dropped out at the end of the first year and a total of 81.8% non-compliant patients dropped out in the first 2 years of SPT. Consequently, this means that after the first 2 years, patients have a low risk of dropping out.[110]

Another retrospective study included 236 patients that had been recommended to attend a SPT-program with a 3-month recall in a private practice. After 3 years 6 patients (2.54%) attended recall four times a year and showed total compliance and 34 patients (14.4%) did not comply for implant maintenance.[77]

A lack of compliance has been shown to increase the risk for problems in peri-implant tissue. To underline the importance of compliance it has to be noted that a significant correlation between increased PPD and lower compliance was found.[77] Even more, the patient's compliance has a significant impact on peri-implant bone loss.[111] The prevalence of peri-implantitis has been reported to be more in individuals with insufficient oral hygiene and in those who did not show up at dental appointments.[30,112] Individuals with established peri-implant mucositis, especially those without preventive maintenance, presented a high incidence of peri-implantitis.[29] The treatment success rate at patient level for patients with acceptable compliance has been reported at 86% and was

significantly higher compared with patients with poor compliance (50%). In addition, the compliance was significantly lower for smokers.[113] Smoking habits, as well as poor compliance were significantly associated with prevalence of peri-implantitis.[114]

Given this, it is not surprising that patient compliance may be of great impact on the peri-implant health, it is important to understand why treated patients do not attend regular recall. The influencing factors for non-compliance have been analysed and it has been established that the "Geographical distance" was the most significant one, followed by "Tobacco smoking" and "Diabetes". "Pre-existing experience in prophylaxis programs" and "Number of Implants" positively impacted the patient compliance.[77] When investigating periodontal patients, a statistically significant difference was established between patients that had received implant treatment or not. In the group of periodontal patients treated with implants 11.9% had insufficient compliance, while 35.2% of the periodontal patients that did not need implants treatment dropped out. It is presumed that an additional surgery, such as the insertion of an implant, may have a psychological impact on patient behaviour, increasing the patient's motivation to go regularly for the scheduled control appointments.[110]

Conclusion

It is clear that implants are susceptible to plaque-related diseases in a very similar way as teeth. Therefore, plaque scores (PI) and gingival inflammation scores (GI) have to be and remain low. Before starting any implant therapy the clinician needs to make certain that the patient has the oral hygiene skills to minimize the risk of developing peri-implant diseases. It is not only important to show how to brush with the different devices. More essential is that they acquire the skills and the knowledge to understand "why" they are used. Furthermore, clinicians have to construct a supra-structure that makes it easy for the patient to perform oral hygiene. It is wise to avoid construction of over-contoured and bulky crowns and bridges that restrict access around implants. It would be incongruous to expect from patients to perform daily plaque control under such bulky constructions when it is even challenging for the clinician to remove supramucosal and submucosal microbial deposits during maintenance visits.

To prevent peri-implantitis, patient's compliance including plaque control and dental follow-up has to be sufficient. Consequently, the inclusion of patients treated with dental implants has to be with large precaution. Every potential risk factor has to be considered and reflected. A specific recall program, individual for each patient, should be established to provide professional care, to detect and prevent the development of peri-implant diseases.

It seems that patients that are compliant in the first few years of scheduled maintenance care tend to remain faithful in a long-term SPT, which may be ensured by the improvement in patient communication and motivation after the end of active therapy. Hence, before treatment, SPT should be presented as essential and necessary part of implant therapy and the benefits should be pointed out constantly.

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Figure legends

Figure 1
The importance of keratinized mucosa (KM) surrounding implant supported restorations should not be underestimated. A band of at least 2mm should be present (A) to facilitate plaque removal and to preserve peri-implant bone height (B). Absence of KM (C) can increase the risk of plaque/food impaction and bone loss may be expected (D).

Figure 2
A narrow proximity of the implants may induce interproximal bone loss due to insufficient vascularity (A). Gingival recession may occur in such cases (B).

Figure 3
Radiological appearance of implant 45 placed to close to the tooth (A). Interdental cleansability is not achievable for the patient and caries distal of tooth 44 has developed (B).

Figure 4
Radiological appearance of two implants, the crown on the 14 has been placed properly, and conversely the crown on the 15 was not well fit to the abutment. This creates a niche for biofilm adherence and unfavourable implant loading that led to peri-implant bone loss.

Figure 5
Over-countered and bulky constructions should be avoided. In this case the implant 36 is relatively small and the crown has an abrupt emergence creating a plaque retentive shelf. Extensive bone loss is visible.

Figure 6
A full edentulous 62 years old patient with a bridge on implants in the lower jaw. Notice the embrasure spacing between implants, it is crucial to control if the patient is able to use interdental brushes.

Figure 7
A bar construction placed deep in the oral vestibule can be challenging to clean for patient with impaired oral hygiene skills (A). Plaque and calculus retention can result in peri-implant bone loss (B).

Figure 8
Radiological aspect of telescopic crowns with well preserved bone level (A, B). Telescopic crowns are easy to clean, especially when surrounded with a sufficient width of keratinized mucosa (C).

Figure 9
A 86 years old patient with a removable bar overdenture. Radiographs show the health peri-implant bone level (A, B). Despite the impaired manual skills the patient is able to self-preform oral hygiene (C).

Table legends and table

Table 1 Oral Hygiene as risk indicator for peri-implantitis

Study (year)	Follow up	# Subjects (# implants)	Criteria	Study design	Relevant results
Lindquist et al (1996)	15 years	27 subjects	/	Prospective study	– 14 subjects had a poor and 13 a good oral hygiene. – In the group with poor oral hygiene mean bone loss of 1.7 mm. – In the group with good oral hygiene mean bone loss of 0.7 mm. – The difference between both groups statistically significant.
Roos-Jansaker et al (2006)	9-14 years	218 subjects (999 implants)	Mucositis = PPD ≥ 4mm and BoP Peri-implantitis = bone loss ≥ 3 threads + BoP and/or pus	Cross-sectional study	– Significant association between presence of plaque and mucositis. OR 1.9 [1.2-2.9] (p=0.005) – No significant association between presence of plaque and peri-implantitis OR 1.7 [0.73-3.8] (p=0.2)
Ferreira et al (2006)	42.5 (SD=17.1) months (mean loading time)	212 subjects (578 implants)	Peri-implant mucositis = BoP Peri-implantitis = PPD ≥ 5mm + BoP and/or pus	Cross-sectional study	– Plaque scores were significantly dose dependent associated with peri-implant diseases. – A very poor oral hygiene (PI >2) had an OR of 14.3 [9.1-28.7] for peri-implantitis, which is much higher when compared to the same level op plaque scores in peri-mucositis (OR = 2.9 [2.0 – 4.1]). – A poor oral hygiene (PI >1 and <2) had an OR of 1.9 [1.2 – 2.3] for peri-mucositis and 3.8 [2.1 – 6.8] for peri-implantitis, which presents lower differences compared to a very poor oral hygiene. – These results were statistically significant (p = 0.002). – Conclusion: a very poor oral hygiene was highly associated with peri-implantitis.
Pontoriero et al (1994)	3 weeks	20 subjects	/	Experimental induced gingivitis and peri-implant mucositis	– After 3 weeks of undisturbed plaque accumulation there was no statistically significant difference between the mean values of plaque index, gingival index, sulcus bleeding index, pocket probing depth and marginal recession at implant compared to tooth sites. – This demonstrated a similar cause-effect relationship between the accumulation of plaque and the development of peri-implant mucositis as the cause-effect, similar to the experimental gingivitis model.
Salvi et al (2012)	3-6 weeks	15 subjects	/	Experimental induced gingivitis and peri-implant mucositis	– Experimental undisturbed plaque accumulation (3 weeks) + 3 weeks of plaque control – During plaque accumulation, both at implants and teeth: increased median plaque and gingival index. However, despite a similar bacterial challenge higher GI was shown at implant sites indicating a more pronounced inflammatory response. – 3 weeks of resumed plaque control was not enough to reach pre-experimental levels of gingival and peri-implant mucosal health. – The crevicular fluid levels of MMP-8 were significantly higher at implants compared with teeth (p < 0.05).

BoP = Bleeding on Probing; PPD = probing pocket depth; OR = Odds Ratio; MMP-8 = matrix-metalloproteinase-8

Table 2 Cleansability as risk indicator for peri-implantitis

Study (year)	Time	Subjects	Patients	Factor affecting cleansability	Relevant results
Bouri et al. (2008)	>1 year implant in place	200I/76P	Patients with 1 or more implant-supported restorations	Width of keratinized mucosa around implants	The mean Gingival Index score, Plaque Index score, and radiographic bone loss were significantly higher for those implants with a narrow zone (<2mm) of keratinized mucosa.
Souza et al. (2015)	>1 year implant in function	270I/80P	Patients with 1 or more implant-supported restorations	Width of keratinized mucosa around implants	Implant sites with a narrow band of keratinized mucosa were shown to be more prone to brushing discomfort, plaque accumulation, and peri-implant soft tissue inflammation.
Schuldt et al. (2014)		161I/27P	Patients with implant-supported fixed prostheses that did not have any routine maintenance care	Interimplant distance	Implants with less than 3 mm inter-implant distance were three times more likely to have peri-implantitis.
Dalago et al. (2016)	>1 year implant in function with final restoration	916I/183P	Patients treated with titanium implants and implant-supported fixed prostheses installed from 1998 to 2012	Total implant rehabilitations vs. single rehabilitations	Total rehabilitations were 16,1 more prone to develop peri-implantitis compared to single rehabilitations.
Heitz-Mayfield et al. (2011)	4 weeks between initial and last measurements	29I/29P	Patients with one implant diagnosed with peri-implant mucositis	Localisation of restauration margin	Non-surgical mechanical debridement and oral hygiene were effective in the treatment of peri-implant mucositis. The results were not enhanced when adjunctive chloorhexidine gel was used. However implants with supramucosal restoration margins showed significantly more reduction in PPD compared to those with submucosal restoration margins.
Frisch et al. (2013)	Mean follow up 5,6±3,5y	80I/20P	Patients with edentulous maxillae restored with overdentures supported by four implants with a Morse taper connection and double crowns and attended an annual maintenance program	Morse taper connection overdentures	Eight implants (10.1%) in two patients (10%) showed peri-implantitis; both active smokers (CSR: 88,75%). One implant was lost (CSR: 98.75%). All dentures were still functional (prosthetic survival rate 100%) possibly due to better accessibility for peri-implant hygiene measures compared to bar constructions.
Rinke et al. (2015)	5-19y of OD function	36OD/27P	Patients who were restored with 36 implant retained overdentures (IODs) with 3 different bar designs (prefabricated round bars, one-piece anterior milled bars and two bilaterally placed milled bars)	Bar-retained overdentures	The survival rates of the prostheses and implants were 100% and 97.7%. Peri-implantitis was diagnosed for 12.4% on implant level and for 37% on patient level.
		28I/14P			Clinical factors: healthy mucosal conditions.

Cune et al. (2010)	>10y implant in function		Patients with two mandibular implants and a overdenture with different types of attachment	Ball-socket and bar-clip overdentures	Radiographic: stable marginal bone levels. PPD around implants provided with ball-socket were slightly shallower than those with bar-clip after 10 years of function.
Naert et al. (2004)	10y implant in function	36P	Patients with two mandibular implants and a overdenture with different types of attachment	Bar, magnet, or ball attachment system	Ball group scored best taking into account the retention of the overdenture, soft tissue complications, and patient satisfaction at year 10.
Serino et al. (2009)	In function: 11 impl >10 years; 5 impl 5-10 years; 7 impl <5 years	23P	Patients presented clinical signs of peri-implantitis around one or more implants and remaining teeth in the same and/or opposite jaw	Accesibiity	High proportion of peri-implantitis implants (48%) were associated with no accessibility for appropriate oral hygiene measures, while implants with good capability to clean were rarely (4%) associated with peri-implantitis. In total 74% of the implants didn't have a good accessibility to proper oral hygiene.
Vandekerckhove et al. (2004)	Measurements on baseline 3,6,12 months	80P	Patients rehabilitated with fixed prostheses on implants who attended an annual follow-up	oscillating/rotating powered toothbrush	After switching from manual to powered tooth brushing periodontal parameters were improving. The mean PPD decreased from 3,3mm at baseline to 3,0mm at 12 months. There was even a slight gain in attachment after 1 year. Consequently the powered toothbrush can be considered safe, comfortable and effective for implant patients.
van Velzen et al. (2015)	3y	10P	Patients with progressive peri-implantitis despite a well developed hygiene protocol (including floss) and professional supra- and submucosal cleaning	Floss vs. Interdental brushes	After explorative surgery all 10 patients presented remnants of dental floss around the rough part of the dental implants. In 9 of the 10 cases peri-implant mucosa improved significantly after debridement. Consequently, the use of interdental brushes or wooden toothpicks is to be preferred in situations with exposed rough dental implant surfaces.

Table 3 Factors negatively involved in cleansability

Surgical	Prosthetic	Patient
Non-keratinized tissue around implants	Limited embrasure spacing between implants	Poor oral hygiene
Wrong angulation of the implant(s)	Bulky crowns	Poor compliance
Surgical trauma	Fixed constructions with too extensive cantilevers	
Implants placement in close proximity	Bar for overdenture too close to gingiva	
Too many implants	Level of the restoration margin	
Wrong positioning of the implant(s)		

Table 4 SPT routine for patient with implants

SPT	Routine
Clinical control	(Table 6)
Radiographic assessment	Because incidence of peri-implantitis is more likely soon after placement, it is advisable to take a radiograph every year for the first 5 years. Afterwards, a radiograph every 3 years or when needed due to clinical changes.
Professional instrumentation	It is advisable to always polish supra-gingivally (also to remark to patient how important it is to keep it clean). When needed, sub-gingival instrumentation with titanium scaler may be performed. Chlorhexidine disinfection may be used as well
Oral hygiene (re)instructions	Always stress the importance of self performed oral hygiene and were needed repeat instructions.

Table 5 SPT and Compliance as risk indicator for peri-implantitis

Study (year)	Follow up	Subjects	Patients	SIT intervals	Relevant results
Cardaropoli & Gaveglio (2012)	5 years	96	Patient treated for periodontitis	SPT/SIT 3, 4 or 6 months intervals according to individual needs	– More than 80% of non-compliant patients dropped out in the first 2 years of SPT. – Periodontal patients with ≥1 implants had a higher rate of compliance with SPT (88.1%) than patients that did not have implant surgery (64.8%)
Corbella et al (2011)	6 months to 5 years	61	Patient with full-arch rehabilitation	6 months for +2 years, then yearly up to 4 years	– Systematic hygienic protocol was effective in preventing peri- implant mucositis as well as in controlling plaque accumulation and clinical attachment loss – Incidence of peri-implant mucositis was less than 10% –
Costa et al (2012)	5 years	80 (39 with SIT, 41 without SIT)	Patients with peri-implant mucositis	Test: At least 1 time a year Control: no maintenance	– Individuals with pre-existing peri-implant mucositis, especially those without preventive maintenance, presented a high incidence of peri-implantitis. – The incidence of peri-implantitis in the "maintenance group" was 18% compared to 43.9% in the group that did not receive maintenance.
Frisch et al (2014)	3 years	236	Patients with implant-supported restorations	Every 3 months	– Non-compliance rate increased over the 3 years – Clinicians who introduce patients to SIT programs with a 3-month recall after implant therapy may expect encouraging compliance rates over the first 3 years – Patients with greater geographical distance may have lower compliance rates
Lagervall & Jansson (2013)	26 ± 20 months	150	Patients referred for peri-implantitis treatment	According to individual needs	– The success rate was significantly lower for patients with poor compliance and a non-acceptable oral hygiene level. In addition, the compliance was significantly lower for smokers. – The effectiveness of the therapy was impaired by severe periodontitis, severe mean marginal bone loss around the implants, poor oral hygiene, and low compliance.
Pjetursson et al (2012)	3–23 years	70	Periodontally susceptible patient treated with implants	According to individual needs	– SIT at the University: 31.9% of the patients had one or more implants affected by peri-implantitis. – SIT at referring practitioners: 52.2% of the patients had one or more implants affected by peri-implantitis.
Rentsch-Kollar et al (2010)	>10 years	147	Patients with an implant overdenture	At least one or two scheduled visits per year	– Compliance was high, with a regular recall attendance of >90% – Visits to a dental hygienist and dentist resulted in an annual visit rate of 1.5 and 2.4, respectively
Rinke et al (2011)	68.2 ± 24.8 months	89	Partially edentulous patients with implants	First year: every 3 months After: every 6 months	– Significant association between peri-implantitis and compliance (OR:0.09; P=0.011)
Roccuzzo et al (2012)	10 years	101	Implants placed in patient with and without a history of periodontal disease	According to individual needs	– A significant difference in peri-implant disease was found between individuals with a history of periodontal disease group adhering or not to SIT. – Patients with a history of periodontal disease must be accounted for a SIT program.
Roccuzzo et al	10 years	123	Implants placed in patient with	According to individual needs	– A significant difference in peri-implant disease was found between individuals with a history of periodontal disease, adhering or not to SIT.

(2014)			and without a history of periodontal disease		–	In individuals without a previous history of periodontitis attending an individualized SIT program the biological complications at implants are low
Serino et al (2015)	5 years	27	SIT on patients surgically treated for peri-implantitis.	6 months	–	In patients with a high standard of oral hygiene and enrolled SIT, the peri-implant conditions were maintained stable for the majority of subjects and implants during a 5-year period
					–	Probing attachment loss occurred in only 13% of the implants in four patients during the 5-year period.
					–	Presence of residual pockets around implants seemed to be a high predictor for disease progression
Vervaeke et al (2015)	>2 years	376	Patients referred for implant treatment	According to individual needs	–	The present study showed more failures in the group of patients responding to the recall invitation after implant placement. As most failures were early failures, this could be interpreted as meaning that patients who experienced implant failure were more compliant compared with patients with successfully integrated implants

SPT = supportive periodontal therapy; SIT = supportive implant therapy; OR = Odds Ratio

Table 6 Supportive periodontal therapy: check points

SPT	How
Medical history	Medical record should always be up to date. Ask for changes in health condition and modification in medications.
Soft tissue condition	Control variation in stability of soft tissue margin (recession) and width of keratinized mucosa.
Plaque, bleeding and suppuration	Note presence of plaque, bleeding and suppuration to compare with previous visits. Repeated oral hygiene instruction may be necessary. The manifestation of bleeding and suppuration may indicate the presence of inflammation.
Probing	Use a specially designed flexible plastic probe to check the implant at 4 places. Increase in depth should be noted and proper therapy instituted.
Occlusion	Check the occlusion of the implant and neighboring teeth to prevent occlusal overload.
Mobility	Mobility could be induced by loss of integration, fracture of the implant or restorative complication (loosening or fracture of the screw or abutment).
Contact point	Control with dental floss. A loose contact point could favors plaque accumulation.