CLINICAL ORAL IMPLANTS RESEARCH

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Peri-implantitis susceptibility as it relates to periodontal therapy and supportive care

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Abstract

Objective: To assess the long-term survival of implants inserted in periodontally susceptible patients and to investigate the influence of residual pockets on the incidence of peri-implantitis and implant loss.

Materials and methods: For 70 patients, comprehensive periodontal treatment was followed by installation of 165 Straumann® Dental implants. Subsequently, 58 patients entered a University supportive periodontal therapy (SPT) program and 12 had SPT in a private practice. The follow-up time ranged from 3 to 23 years (mean 7.9 years). Bleeding on probing (BOP), clinical attachment level (CAL), and peri-implant probing depths (PPD) were evaluated at baseline (T0), completion of active treatment (T1), and at follow-up (T2). Peri-implant bone levels were assessed on radiographs at T2. Patients were categorized as having implants not affected by peri-implantitis (non-PIP), or affected by peri-implantitis (PIP).

Results: From 165 implants inserted, six implants were lost, translating into a cumulative survival rate of 95.8%. Solid screw implants yielded significantly higher survival rates than the hollow cylinder and hollow screw implants (99.1% vs. 89.7%). Implants lost due to peri-implant infection were included in the PIP groups. When peri-implantitis (PPD $\geq$ 5 mm, BOP+) was analyzed, 22.2% of the implants and 38.6% of patients had one or more implants affected by peri-implantitis. Using the peri-implantitis definition (PPD $\geq$ 6 mm, BOP+), the prevalence was reduced to 8.8% and 17.1%, respectively. Moreover, all these implants demonstrated significant ($\geq$ 2 mm) bone loss at T2.At T1, the non-PIP group had significantly ($P = 0.011$) fewer residual pockets ($\geq$ 5 mm) per patient than the PIP group (1.9 vs. 4.1). At T2, the PIP group displayed an increased number of residual pockets compared to T1, whereas in the non-PIP group, the number remained similar to T1. At T2, mean PPD, mean CAL and BOP were significantly higher in the PIP group compared with the non-PIP group. The prevalence of peri-implantitis was lower in the group that was in a well organized SPT at the University.

Conclusions: In periodontitis susceptible patients, residual pockets (PPD $\geq$ 5 mm) at the end of active periodontal therapy represent a significant risk for the development of peri-implantitis and implant loss. Moreover, patients in SPT developing re-infections are at greater risk for peri-implantitis and implant loss than periodontally stable patients.

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The use of oral implants has become integral to comprehensive dental care. Today, the application of oral implants in replacing one or several missing teeth, in partially edentulous patients represents a frequent indication (Buser et al. 2008). The primary advantage of using oral implants in this indication lies in the fact that teeth may be replaced without the need of preparing adjacent teeth to anchor fixed dental prostheses (FDP), thereby preserving natural tooth structure (Preist 1999). Moreover, shortened dental arches

may, if indicated, be extended with implant supported short-span fixed dental prosthesis (Brägger et al. 1990). Although the long-term survival of oral implants in the partially edentulous oral cavity is well documented and high (Berglundh et al. 2002; Pjetursson et al. 2004; Holm-Pedersen et al. 2007; Jung et al. 2008), systemic and/or local conditions may affect long-term survival or success of such treatment. Oral implants will naturally be exposed to the individual ecological conditions present in the aqueous environment of the oral cavity and hence, bio-film formation on implant surfaces occurs predictably (Lang et al. 2000). As a matter of fact, sterile oral implants are colonized by microbes within half an hour following their placement into the oral cavity (Fürst et al. 2007), and this bacterial colonization appears to be predictive for the microbiota found in peri-implant sulci after 1 year (Salvi et al. 2008).

Several studies have suggested that in partially edentulous patients, periodontal pathogens may be transmitted from periodontally compromised teeth to newly installed implants implying that periodontal niches may serve as reservoirs for bacterial colonization (Apse et al. 1989; Quirynen & Listgarten 1990; Leonhardt et al. 1992, 1993; Kohavi 1993; Koka et al. 1993; Mombelli et al. 1995; Lee et al. 1999). The importance of treating existing periodontitis prior to the placement of dental implants has often been emphasized (i.e. Mombelli et al. 1995; Heitz-Mayfield & Lang 2010). It has also been shown that periodontal conditions are correlated with the clinical condition diagnosed at implant sites (Brägger et al. 1997) indicating the possibility of spread of infection from periodontally incompletely treated sites to the peri-implant sulci (Mombelli et al. 1995). *Aggregatibacter actinomycetemcommitans* and *Porphyromonas gingivalis* were more frequently present in partially edentulous patients compared to totally edentulous patients (Mombelli et al. 1987; Kalykakis et al. 1994). Implant sites harboring *A. actinomycetemcommitans*, *P. gingivalis* or *Prevotella intermedia* demonstrated deeper peri-implant probing depths (PPD) along with clinical signs of inflammation (Kalykakis et al. 1994). Implant sites exposed to the oral environment for 3–4 years showed deeper probing depths than those with a shorter exposure. Periodontal pathogens identified in residual periodontal pockets at the time of implant installation were found adjacent to the newly installed implants 3 and 6 months later indicating the spread of pathogens (Mombelli et al. 1995).

Some authors expressed little or no concern about installing implants in patients with a history of periodontitis (Nevins & Langer 1995; Nevins 2001), whereas others pointed to the fact that patients susceptible to periodontitis may be affected by peri-implant diseases more frequently than non-susceptible patients (Ellegaard et al. 1997; Karoussis et al. 2003, 2004). In that respect, in a longitudinal study of implants installed in patients previously affected by periodontitis, the presence of putative periodontal pathogens at peri-implant and periodontal sites did not appear to predict future attachment loss or implant failures (Sbordone et al. 1999).

In contrast, a 10-year prospective cohort study involving 53 patients with 112 hollow screw implants (Straumann® Dental Implant System, Straumann AG, Basel, Switzerland) revealed that implants inserted as replacement of periodontally involved teeth exhibited lower survival and significantly lower success rates at various threshold levels of bleeding on probing and probing depths, as well as a significantly greater number of biological complications than implants placed in patients without a history of periodontitis (Karoussis et al. 2003). In this study, hollow and perforated screw type implants with titanium-plasma-sprayed (TPS) surfaces (HS Implants, Straumann AG, Basel, Switzerland) were assessed. These implants may have exhibited a potentially greater risk for biological complications and subsequent failure due to their design and surface characteristics. Moreover, these designs are no longer available in the market today.

A recent systematic review (Ong et al. 2008) concluded on the basis of nine studies that there was evidence that patients treated for periodontitis may experience more implant loss and biological complications than non-periodontitis patients. However, methodological issues limited the potential for drawing robust conclusions.

The purpose of the present study was, therefore, to further assess the long-term survival and success of solid screw, hollow screw and hollow cylinder implants in a patient cohort with a history of periodontal disease and to investigate the influence of residual pockets at the end of active periodontal treatment on the incidence of peri-implantitis and implant loss.

Materials and methods

During the period between the years 1978 and 2002, a total of 392 patients were treated according to the protocol of comprehensive periodontal therapy at the Department of Periodontology and Fixed Prosthodontics, University of Berne, Switzerland. Implant therapy was incorporated as part of comprehensive care in 1988.

Following a comprehensive examination and treatment planning (T0), the treatment consisted of cause-related initial periodontal therapy including case presentation, oral hygiene instruction, and scaling and root planing under local anesthesia if necessary. After re-evaluation of the outcomes of initial therapy, periodontal surgery was performed if indicated (Pocket Probing Depths (PPD) $\geq$ 6 mm). Treatment outcomes after completion of periodontal therapy were assessed (T1). Eventually, prosthetic therapy using implant- or tooth-supported FDPs was performed.

Subject cohort

From the 392 treated patients, 199 could be recruited and re-examined during 2005 (T2). The remaining 193 patients were either deceased, had moved away from the area or were too frail to participate in the re-examination.

For the patients to be included in this study at least two additional sets of periodontal and radiological examinations at baseline (before therapy, T0) and at the end of active periodontal therapy (T1) had to be available. Finally, 172 patients, 95 (55.2%) women and 77 (44.8%) men, between 14 and 69 years of age (Mean: 45 ± 11 years) at baseline (T0) were included in the analysis. The remaining 27 patients could not be analyzed owing to the lack of a complete documentation. Using the periodontal parameters of the baseline examination (T0), all patients were classified as having Level 1 or 2 periodontitis according to the definition of a periodontal case proposed at the 5th European Workshop on Periodontology (2005) (Tonetti & Claffey 2005).

From the 172 patients selected, 70 patients had one or more dental implants (Straumann AG ®; Basel, Switzerland) inserted during the comprehensive treatment. From the total of 177 implants inserted, 165 were inserted as part of the initial active therapy (corrective phase), and additional 12 implants were placed later during SPT. From the 165 implants originally placed detailed information was available for 161 implants.

The majority or 105 implants were inserted in the maxilla and the remainder of 60 in the mandible. Regarding implant type, 115 were solid screws implants with a TPS or a sandblasted large grit and acid attacked surface

and 50 were hollow screw and hollow cylinder implants with a TPS surface (Table 1). Thirty-five of the implants were placed in the anterior area, 74 in a premolar position and 52 in a molar position.

The most frequently used implant length was 10 mm (74 implants), followed by 8 mm implants (58) and 12 mm implants (23). Only 6 of the 161 implants were short 6 mm implants (Table 1).

Following the completion of treatment, 47 patients (67.1%) attended the supportive periodontal therapy (SPT) program at the University of Berne and twenty-three patients (32.9%) were referred back to the referring private practitioners for maintenance care.

Clinical examinations

At baseline (T0), before the initiation of the initial treatment, comprehensive periodontal and radiological examinations were performed. Probing pocket depth (PPD) and recession were measured at six sites per tooth to calculate the clinical attachment level (CAL). Bleeding on probing (BOP) was recorded at four sites per tooth, and full-mouth bleeding scores were obtained. Tooth mobility (Ramfjord 1967) as well as furcation involvement of multi-rooted teeth (Hamp et al. 1975) were assessed. A full-mouth periapical x-ray status was performed and radiographic bone loss was evaluated. The same periodontal and radiological examinations were performed at the end of active therapy (T1) and at re-evaluation (T2). At the re-evaluation (T2), the full-mouth radiographs were replaced by orthopantomograms (OPT).

Definition of peri-implantitis

Two definitions of peri-implant mucositis or peri-implantitis were utilized (Levels 1 & 2):

In the first analysis, the Level 1 was defined as sites with PPD $\geq$ 5 mm and BOP positive (Mombelli & Lang 1994).

In the second analysis, the threshold for Level 2 was set at PPD $\geq$6 mm and BOP positive (Mombelli & Lang 1994).

On radiographs, peri-implantitis was defined as implants yielding radiographic marginal bone levels of $\geq$5 mm below the implant shoulder (IS). This equaled a marginal bone loss of $\geq$2 mm compared to what can be expected as a normal remodeling for a transmucosal implant with a 2.8 mm machined neck.

Smoking and health status

Using a questionnaire at the re-evaluation (T2), smoking habits at the time point T2, the health status at time point T2 and the frequency of recall visits during SPT were assessed.

Radiographic examination

Orthopantomograms (OPT) were obtained at the time of re-evaluation (T2). To perform the measurements, the OPTs were captured using a black and white video camera (Canon; Still Video Products Group, Tokyo, Japan) and viewed on a light box. The images were transferred to a computer and digitized with frame grabber hardware (Matrox Electronic Systems MVP/AT; Dorval, Quebec, Canada). Using image-processing software, digitized images were stored with a resolution of 512 × 512 × 8 bit pixels (256 shades of gray). Stored images were then displayed on a monitor, and linear measurements were performed with the help of a cursor (Brägger 1996) by a calibrated examiner. The measurements were all repeated at two time intervals. The magnifying factor of the OPTs was estimated by measuring the known distance between implant treads.

The following measurements were made:

Marginal bone level – the distance from the IS to the alveolar bone crest (AC), mesially and distally.

Statistiscal analysis

Data were entered in a computer data base and corrected for implausible entries. Stratified descriptive information on mean CAL and PPD as well as percentage of BOP for each patient, were calculated over all recorded sites. Comparisons between the two groups of patients were made by means of *t*-tests. For implant loss, the unit of analysis was the implant. Cumulative survival or cumulative incidence estimates and their 95% confidence intervals (CI) derived from Kaplan–Meier calculations were provided (Kaplan & Meier 1958). The survival curves for implants using the log-rank test were compared.

All analyses were conducted using Stata version 11 (Stata Corporation, College Station, Texas, USA).

Results

At the re-evaluation visit (T2), based on the entire patient cohort, 36.9% of the patients were non-smokers, 35.7% were former smokers, and 27.4% were current smokers. Of these, 28.3% of the smokers were light smokers (1–9 cig/day), 26.1% moderate (9–19 cig/day), and 45.6% were heavy smokers ($\geq$20 cig/day).

Survival and failure rates

From a total of 165 dental implants inserted as part of the initial active therapy, six implants were lost during the follow-up period. Two implants were lost in the first year of function, one implant was lost in the second year and another implant in the third year of function. The fifth and the sixth implants were lost after 6 years of function. Hence, the cumulative survival rate after a mean follow-up time of 7.9 years was 95.8% (95% CI: 90.9–98.1%). Implant survival was also calculated according to implant types. From 115 solid screw implants, only one was lost, translating into a cumulative survival rate of 99.1% (95% CI: 93.9–99.9%) after a mean follow-up time of 6.4 years (Table 2). Five of 50 hollow screw or hollow cylinder implants were lost giving a cumulative survival rate of 89.7% (95% CI: 77.0–95.6%) after a mean follow-up time of 11.1 years (Table 2). The difference in implant loss between solid screw and hollow implants reached statistical significance ($P = 0.008$).

Peri-implant soft tissue conditions

At the re-evaluation (T2), the 70 patients included had a total of 171 implants. These implants consisted of the 159 implants surviving the entire observation period from the 165 implants originally placed during initial active therapy. In addition, 12 implants had been installed during the follow-up period (totaling 171 implants).

For the evaluation of peri-implant soft tissue conditions, all 171 implants were included. At the time of re-evaluation (T2), 22.2% of the implants were affected by peri-implantitis Level 1 (PPD $\geq$5 mm and BOP positive (Mombelli & Lang 1994)) or were lost due to peri-implantitis during the observation period. Moreover, on a patient level, 27 of the 70 patients (38.6%) had one or more implants affected by peri-implantitis or had lost implants due to peri-implantitis (Table 2).

On the other hand, when the threshold for the definition of peri-implantitis Level 2 was set at PPD $\geq$6 mm and BOP positive (Mombelli & Lang 1994), the incidence of peri-im-

Table 1. **Distribution of implants installed according to design, location and length [Numbers and proportions (%)]**

Implant length	6 mm 6 (3.7%)	8 mm 58 (36%)	10 mm 74 (46%)	12 mm 23 (14.3%)
Location	Anterior 35 (21.7%)	Premolar 74 (46.0%)	Molar 52 (32.3%)	
Implant design	Hollow screw 25 (15.2%)	Solid screw 115 (69.6%)	Hollow cylinders 25 (15.2%)	

Table 2. **Cumulative survival rate for solid screw and hollow cylinder/screw implants**

	Solid screw implants				Hollow cylinder/screw implants			
Time (years)	Number of implants	Implants lost	Survivor function	95% CI	Number of implants	Implants lost	Survivor function	95% CI
1	114	1	0.991	0.939–0.999	50	1	0.980	0.866–0.997
2	110	0	0.991	0.939–0.999	49	1	0.960	0.849–0.990
3	102	0	0.991	0.939–0.999	47	1	0.940	0.824–0.980
4	95	0	0.991	0.939–0.999	47	0	0.940	0.824–0.980
5	82	0	0.991	0.939–0.999	45	0	0.940	0.824–0.980
6	70	0	0.991	0.939–0.999	43	2	0.897	0.770–0.956
7	56	0	0.991	0.939–0.999	43	0	0.897	0.770–0.956
8	38	0	0.991	0.939–0.999	42	0	0.897	0.770–0.956
9	18	0	0.991	0.939–0.999	40	0	0.897	0.770–0.956
10	10	0	0.991	0.939–0.999	38	0	0.897	0.770–0.956

plantitis or implants lost due to peri-implantitis over a mean observation period of 8 years was reduced to 8.8% on an implant level and to 17.1% on a patient level.

Radiographic examination

Linear measurements to evaluate the marginal bone levels were performed on digitized images and could be made for 152 of the 171 implants. With the help of a cursor, the marginal bone level [the distance from IS to the first bone-to-implant contact (BIC)] was measured. Performing a frequency analysis, 78.3% of the implants showed stable bone levels between 0 and 3 mm (2.8 mm polished neck included) from the IS, 17.1% of the implants had marginal bone levels 0–1 mm below the expected marginal bone level for tissue level Straumann® implants with a 2.8 mm machined neck, and 4.6% of the implants demonstrated significant ($\geq$2 mm) bone loss.

Periodontal conditions of peri-implantitis Level 1 group

The patients were divided into two groups (Table 3). A group of 43 patients with implants not affected by peri-implantitis (non-PIP) and a group of 27 patients with one or more implants lost or affected by peri-implantitis (PIP) Level 1 according to the definition of PPD $\geq$5 mm and BOP positive.

At end of active treatment (T1), the non-PIP group had a mean PPD of 2.44 mm, a mean CAL of 3.65 mm and 16.1% of the sites with BOP compared with a PPD of 2.57 mm, a CAL of 3.64 mm and 20.4% BOP for the PIP Level 1 group. This difference in mean PPD, mean CAL and BOP did not reach statistical significance ($P = 0.127$, $P = 0.967$ and $P = 0.182$). However, evaluating the number of residual pockets ($\geq$5 mm), at the end of active treatment (T1), the non-PIP group had significantly ($P = 0.022$) fewer residual pockets per patient than did the PIP group Level 1, 1.9 residual pockets per patient (1.5% of sites) vs. 4.1 residual pockets per patient (3.1% of sites).

At the re-evaluation (T2), the PIP group Level 1 had significantly higher mean PPD ($P < 0.0001$). Furthermore, the BOP in the residual dentition was significantly ($P = 0.006$) higher in the PIP group (25.9%) compared with the non-PIP group (17.6%).

For the non-PIP group, the number of residual pockets was similar at follow-up time (T2) to that at end of active therapy (T1) (1.9 pockets or 1.5% of sites).

On the other hand, in the PIP group Level 1, the number of residual pockets had increased significantly from T1 to T2 (6.4 pockets or 5.4% of sites). The difference in number of residual pockets at T2 between the non-PIP and the PIP group was highly significant ($P < 0.0001$).

Periodontal conditions of peri-implantitis Level 2 group

For this analysis the patients were also divided into two groups (Table 3). The PIP Level 2 group consisted of 12 patients with one or more implants lost due to or affected by peri-implantitis according to the definition of PPD $\geq$6 mm and BOP positive and a group of 58 patients with no implants affected by peri-implantitis (non-PIP).

At end of active treatment (T1), the non-PIP group had a mean PPD of 2.48 mm, a mean CAL of 3.60 mm and 18.7% of the sites with BOP compared with a PPD of 2.52 mm, a CAL of 3.87 mm, and 13.7% BOP for the PIP Level 2 group. This difference in mean PPD, mean CAL and BOP did not reach statistical significance ($P = 0.740$, $P = 0.344$ and $P = 0.233$). At the end of active treatment, the non-PIP group had an average of 2.6 residual pockets ($\geq$5 mm), compared with 3.4 residual pockets in the PIP group. This difference, however, did not reach statistical significance ($P = 0.514$).

At the re-evaluation (T2), the PIP group Level 2 had significantly higher mean PPD ($P = 0.001$) and mean CAL ($P = 0.023$). The BOP in the residual dentition was higher in the PIP group (25.8%) compared with the

Table 3. **Clinical parameters at the end of active therapy (T1) and at the follow-up (T2) (average 7.9 years) for the patient groups with peri-implantitis (PIP) (Level 1: PPD $\geq$5 mm), the patient group with peri-implantitis (PIP)(Level 2: PPD $\geq$6 mm) and the healthy (non-peri-implantitis) patient groups (HP). BOP, Individual mean Bleeding on Probing percentage; PPD$\geq$, Residual PPD after active therapy either 5 mm or 6 mm; Mean PPD, Mean probing depth of the dentition**

	Peri-implantitis Level 1 (PPD 5 mm, BOP+)		Peri-implantitis Level 2 (PPD 6 mm, BOP+)		Non-peri-implantitis		
	T1 $n = 27$	T2	T1 $n = 12$	T2	T1 $n = 43$	T2 $n = 58$	*P*-values
BOP %	20.4%	25.9%	13.7%	25.8%	16.1% 18.7%	17.6% 19.7%	$P = 0.182$, 0.006 $P = 0.233$, 0.126
PPD $\geq$5 mm	4.1 (3.1%)	6.4 (5.4%)	3.4 (2.5%)	8.2 (7.1%)	1.9 (1.5%) 2.6 (2.0%)	1.9 (1.5%) 2.7 (2.2%)	$P = 0.022$, 0.0001 $P = 0.583$, 0.0001
Mean PPD (mm)	2.57	2.21	2.52	2.91	2.44 2.48	1.87 2.31	$P = 0.127$, 0.0001 $P = 0.740$, 0.001
Mean CAL (mm)	3.64	3.26	3.87	3.53	3.65 3.60	3.05 3.04	$P = 0.967$, 0.209 $P = 0.344$, 0.023

non-PIP group (19.7%). This difference did not reach statistical significance ($P = 0.126$).

For the non-PIP group, the number of residual pockets (2.7) was similar at follow-up time (T2) to that at end of active therapy (T1). On the other hand, in the PIP group Level 2, the number (6.2 pockets or 7.1% of sites) of residual pockets had increased significantly from T1 to T2. The difference in number and percent of residual pockets at T2 between the non-PIP and the PIP group was highly significant ($P = 0.0001$).

Supportive periodontal therapy (SPT)

The prevalence of peri-implantitis was evaluated for the group of 47 patients that attended the SPT program at the University of Berne and by the group of twenty-three patients that were referred back to the referring private practitioners for maintenance care.

In the former group that was included in a well-organized and regularly performed SPT at the University, 31.9% of the patients had one or more implants affected by peri-implantitis Level 1 or lost due to peri-implantitis compared with 52.2% of the patients that were referred back to the referring practitioners for SPT. When, analyzed for peri-implantitis Level 2 or implants lost due to peri-implantitis, the prevalence was reduced to 14.9% for the University patients and 21.7% for the patients that had SPT in a private practice. For both peri-implantitis Levels 1 and 2, this difference did not reach statistical significance ($P = 0.102$ and $P = 0.475$).

When the same analysis was done on an implant level, 17.6% of the implants inserted in patients that had the SPT at the University and 30.2% of the implants inserted in patients that had the SPT in a private practice were affected by peri-implantitis Level 1 or had been lost due to peri-implantitis. Moreover, the incidence of implants affected by peri-implantitis Level 2 or lost due to peri-implantitis was 8.3% for the University patients and 9.5% for the patients that had the SPT in a private practice. This difference did not reach statistical significance for peri-implantitis Level 1 ($P = 0.057$) and peri-implantitis Level 2 ($P = 0.791$).

Discussion

This retrospective analysis of patients susceptible to and comprehensively treated for periodontitis and subsequently receiving implant therapy has demonstrated that those patients experiencing recurrent periodontitis yielded a significantly greater risk for the development of peri-implantitis than did the control group with a stable periodontal situation during maintenance. In this regard, the study is in agreement with results of previous reports of patient cohorts susceptible or not susceptible to periodontitis (Ellegaard et al.1997; Hardt et al. 2001; Karoussis et al. 2003).

The prospective cohort previously presented (Karoussis et al.2003) encompassed 53 patients with 112 hollow screw implants. Among these were eight patients susceptible to periodontitis and 45 patients without a history of periodontitis with 21 and 91 implants, respectively. Although the survival rate after 10 years was 90.5% for the susceptible group, it was 96.5% for the non-susceptible group. This difference over 10 years in incidence of implant loss did not reach statistical significance owing to the fact that the difference was made up by only one implant out of a total loss of five.

Over the years, implant systems, implant designs, and implant surfaces have not been considered a major factor regarding the longevity of implants inserted in patients susceptible to periodontitis (Matarasso et al. 2010). In the present retrospective analysis, two types of implants were utilized. Surprisingly, the survival rate of solid screw implants (99.1%) was significantly higher than the survival of hollow screw and hollow cylinder implants (89.7%). One of the explanations for this difference could be that the mean follow-up for the hollow implants was longer than that for the solid screw implants, 11.1 vs. 6.4 years, respectively. Nevertheless, the survival for the hollow TPS implants was already below 90% after 6 years. Another explanation could be that the implant surface and geometry also influenced the success of the implant treatment in periodontally susceptible patients. That would be in agreement with an experimental study in dogs (Albouy et al. 2008) that analyzed the tissue reaction to a ligature induced experimental peri-implantitis around commercially available dental implants. After 12 weeks of active breakdown, when 40–50% of the supporting bone was lost, the ligatures were removed and plaque was allowed to accumulate for additional 24 weeks. The authors concluded that the implant surface was a significant factor influencing the amount of tissue breakdown occurring during the experimentally ligature-induced peri-implantitis.

In the present study, cohorts were defined on the basis of the prevalence of peri-implantitis. Two thresholds (Level 1 & 2) for this definition were applied choosing either ≥ 5 mm PPD (Level 1) or ≥ 6 mm PPD (Level 2) concomitant with a positive BOP score. In addition, the patients with implants lost as a result of infection ($n = 6$) were also included in the cohort affected by peri-implantitis (PIP group). Consequently, the incidence over 8 years was 38.6% or 27 patients for peri-implantitis Level 1. If the peri-implantitis threshold of PPD ≥ 6 mm (Level 2) was applied together with positive BOP scores and including the implant losses, the 8-year incidence was reduced to 17.1% of the patients. In comparison, a study of a patient cohort treated with another implant system than the one assessed in the present study, revealed a peri-implantitis prevalence of 28% of the patients with progressive bone loss after 5–20 years (mean: 9.1 years) (Fransson et al. 2005). On the implant level, however, 12.4% of the implants displayed progressive bone loss. In the present study, 8.8% of implants were lost due to bone loss or demonstrated significant (≥ 2 mm) bone loss.

In another retrospective study over 9–14 years (Roos-Jansåker et al. 2006), the prevalence of peri-implantitis on the patient level was 16%, whereas 6.6% of the implants yielded peri-implantitis. In agreement with these studies, the results of the present analysis demonstrated that the prevalence on the patient level was substantially higher than that on the implant level irrespective of the threshold of probing depth chosen for the definition of peri-implantitis.

Although all patients of the present study were successfully treated for existing periodontitis and hence, were susceptible to periodontitis, they displayed various numbers of residual pockets defined as PPD ≥ 5 mm at the termination of active therapy (T1). This, in turn, means that some patients were treated more successfully than others. Of the patients, later belonging to the PIP group, the mean PPD and BOP were similar to the values assessed for the non-PIP group at the end of active treatment. At the time of re-assessment, approximately 8 years later, these values were significantly different. The mean BOP percentage at T2 was 25.9% for the PIP Level 1 group vs. 17.6% for the non-PIP group. On the other hand, at the end of active treatment, the PIP Level 1 group averaged 4.1 residual pockets compared to 1.9 such pockets in the non-PIP group. This points to the importance of clinical parameters of inflammation and residual periodontal niches as a reservoir for bacterial spread throughout the dentition including the newly

placed implants (Mombelli et al. 1995). The differences in residual pockets and BOP were important risk indicators at T2. Moreover, there was a significant contribution of the number of residual pockets at T1 to the prediction of future peri-implant infections. Thus, it appears reasonable to treat periodontitis to a level of absence of or minimal inflammation as well as to an absence of residual pockets following active therapy to reduce a possible influence of ecological niches on the integrity of implants and their stability.

In the present study, 17.1% of the implants were affected by peri-implantitis Level 1 during the course of 8 years. Moreover, 4.2% of the implants were lost as a result of peri-implant infection. Not considering the early losses ($n = 2$) during the first year, a loss of 3% within the subsequent 7 years represents a very low prevalence compared with systematic reviews on implant failures (Berglundh et al. 2002; Pjetursson et al. 2004). Furthermore, if the TPS hollow cylinder and hollow screw implants are excluded from the analysis, a survival rate of 99.1% for the solid screw implants must be considered very high, especially in a cohort consisting solely of periodontally susceptible patients. It is obvious that with 17.1% of the implants being affected by peri-implantitis revealed by this retrospective analysis, there is a substantial need for diagnosis and treatment of peri-implant diseases. In this respect, the Level 2 definition with $\geq$6 mm PPD and BOP positive may serve as a standard for intervention. This assumption is substantiated by the fact that radiographic bone loss exceeding the remodeling process was recognized in 21.7% of implants. Since only 4.6% of the implants yielded substantial bone loss, it may be speculated that 1 in 20 implants requires advanced rescue measures to treat a peri-implantitis lesion over a period of 8 years (Fig.1).

The implant longevity may significantly depend on the mode and frequency of SPT organized for patients susceptible to periodontitis rather than the implant systems applied (Matarasso et al. 2010). In this study comparing two implant systems in groups of patients with a history of periodontitis or periodontally healthy conditions, statistically significantly higher mean bone loss and numbers of sites with bone loss $\geq$3 mm were identified in patients with a history of periodontitis (Matarasso et al. 2010).

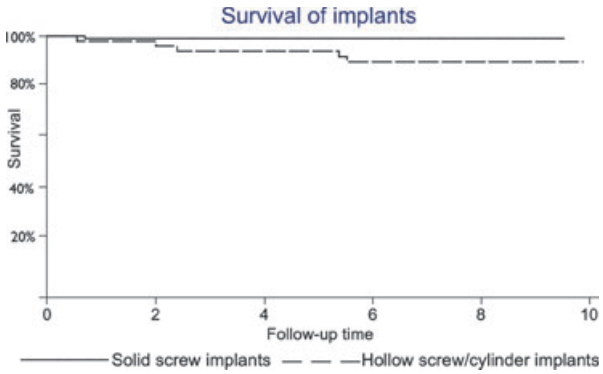

Fig 1. Cumulative survival rate for solid screw and hollow cylinder/screw implants.

Recently, 112 partially edentulous patients were assessed 10 years after implant installation with regard to adhesion to SPT (Roccuzzo et al. 2010). Patients were treated for moderate and severe periodontitis (periodontally compromised patients (PCP)) and compared to patients in periodontally healthy conditions (PHP). During the period of observation, 18 implants were removed because of biological complications. The implant survival rate was thus 96.6% for PHP, 92.8% for moderate PCP and 90% for severe PCP implants. A statistically significant difference was found between PHP and severe PCP. Lack of adhesion to SPT was correlated with a higher incidence of bone loss and implant loss. Hence, the authors concluded that patients with a history of periodontitis presented a lower implant survival rate and a statistically significantly higher number of sites with peri-implant bone loss. Moreover, the authors concluded that patients who did not completely adhere to the SPT, presented a higher implant failure rate. Hence, the value of the SPT in enhancing the long-term outcomes of implant therapy was documented, particularly in subjects affected by periodontitis (Roccuzzo et al. 2010).

In the present study, differences in the prevalence of peri-implantitis were seen between the patients that had been incorporated into a well-organized SPT program at the University and those who had been referred for maintenance care to their referring private practitioners. However, these differences did not reach statistical significance, most likely owing to the fact that a relatively small number of implants were diagnosed as peri-implantitis Level 2. Yet, the present study also provides additional evidence that supports the importance of well-organized SPT for periodontally susceptible patients that have received dental implants.

In conclusion, in periodontitis susceptible patients, residual pockets (PPD $\geq$5 mm) at the end of active periodontal therapy represent a significant risk for the development of peri-implantitis and implant loss. Moreover, patients in SPT developing re-infections are at greater risk for peri-implantitis and implant loss than periodontally stable patients.

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