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Long-term implant prognosis in patients with and without a history of chronic periodontitis: a 10-year prospective cohort study of the ITI[®] Dental Implant System

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Key words: chronic periodontitis, peri-implantitis, success, survival, smoking

Abstract:

Aim: The aim of this 10-year study was to compare the failure, success and complication rates between patients having lost their teeth due to periodontitis or other reasons.

Material and methods: Fifty-three patients who received 112 hollow screw implants (HS) of the ITI[®] Dental Implant System were divided into two groups: group A – eight patients with 21 implants having lost their teeth due to chronic periodontitis; group B – forty five patients with 91 implants without a history of periodontitis. One and 10 years after surgical placement, clinical and radiographic parameters were assessed. The incidences of peri-implantitis were noticed over the 10 years of regular supportive periodontal therapy.

Results: Success criteria at 10 years were set at: pocket probing depth (PPD) \leq 5 mm, bleeding on probing (BoP–, bone loss $<$ 0.2 mm annually. The survival rate for the group with a past history of chronic periodontitis (group A) was 90.5%, while for the group with no past history of periodontitis (group B) it was 96.5%. Group A had a significantly higher incidence of peri-implantitis than group B (28.6% vs. 5.8%). With the success criteria set, 52.4% in group A and 79.1% of the implants in group B were successful. With a threshold set at PPD \leq 6 mm, BoP– and bone loss $<$ 0.2 mm annually, the success rates were elevated to 62% and 81.3% for groups A and B, respectively. Relying purely on clinical parameters of PPD \leq 5 mm and BoP–, the success rates were at 71.4% and 94.5%, and with a threshold set at PPD \leq 6 mm and BoP–, these proportions were elevated to 81% and 96.7% for groups A and B, respectively.

Conclusions: Patients with implants replacing teeth lost due to chronic periodontitis demonstrated lower survival rates and more biological complications than patients with implants replacing teeth lost due to reasons other than periodontitis during a 10-year maintenance period. Furthermore, setting of thresholds for success criteria is crucial to the reporting of success rates.

Date:

Accepted 15 May 2002

To cite the article:

Karoussis IK, Salvi GE, Heitz-Mayfield LJA, Brägger U, Hämmerle CHF, Lang NP. Long-term implant prognosis in patients with and without a history of chronic periodontitis: a 10-year prospective cohort study of the ITI[®] Dental Implant System
Clin. Oral Impl. Res. 14, 2003; 329–339

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ISSN 0905-7161

Osseointegrated titanium oral implants were first used to serve as anchors for prosthetic reconstructions in fully edentulous patients to increase their subjective chewing comfort (Adell et al. 1981; Babbush et al. 1986; Mericske-Stern et al. 1994). Later on, implants were widely used for the replacement of missing teeth in

partially edentulous patients. Thus, the scope of indications was expanded to avoid the preparation of intact or previously successfully crowned neighboring teeth (Priest 1999). Furthermore, the replacement of one or several strategically important, but missing tooth abutments help facilitate the restoration of short or

extended edentulous segments of the dentition (Jemt et al. 1989; Brägger et al. 1990; Jemt & Lekholm 1993).

It is generally accepted that the installation of osseointegrated oral implants in partially edentulous patients represents an efficacious therapy for supplementing natural teeth with implant abutments (Jemt 1986; Jemt et al. 1989; Zarb & Schmitt 1989; Gunne et al. 1992; Jemt et al. 1992; Jemt & Lekholm 1993; Nevins & Langer 1993; Gunne et al. 1994; Lekholm et al. 1994). By installing oral implants into a partially edentulous dentition, the ecological conditions of the oral cavity influencing biofilm formation on implants may vary from that of totally edentulous patients (Mombelli et al. 1995). Thus, residual periodontal pockets may represent niches of infection for adjacent implants. Hence, the importance of periodontal treatment of the residual dentition prior to placement of osseointegrated oral implants has been emphasized (Brägger 1993).

Already 1 year after implant placement, the overall individual periodontal conditions were significantly correlated with the clinical conditions of the tissues around implants (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).

Actinobacillus actinomycetemcomitans and *Porphyromonas gingivalis* were more frequently detected in partially than in totally edentulous patients (Kalyakakis et al. 1994). Moreover, implant sites harboring *A. actinomycetemcomitans*, *P. gingivalis* or *Prevotella intermedia* demonstrated deeper peri-implant probing depths (PPD) concomitantly with clinical signs of inflammation. At sites of implants having been in function for 3–4 years, deeper probing depths and higher detection frequencies of periodontal pathogens were observed compared to sites of implants having been in function for only 1–2 years, thus providing evidence for the spread of pathogens with time. Several studies have indicated that in partially edentulous patients, periodontal pathogens might be transmitted from teeth to implants, implying that periodontal niches may serve as reservoirs for bacterial colonization (Apse et al. 1989; Quirynen & Listgarten 1990; Leonhardt et al. 1992, 1993; Koka et al. 1993; Kohavi et al. 1994; Mombelli et al.

1995). Periodontal pathogens have also been implicated in the development of peri-implant infections (Mombelli et al. 1987; Mombelli & Lang 1992).

Up to now, some authors (Nevins & Langer 1995; Nevins 2001) expressed only minor concern to install implants in patients with a previous history of periodontitis. This was based on a report of such patients after an evaluation period of 1–8 years. The success rates for over 300 implants over this wide variety of observation periods was 97–98%. Nevertheless, 2% of the implants yielded substantial bone loss to the fourth thread of machined-surface oral implants. Reevaluating the Astratech[®] and the ITI[®] Dental Implant Systems in previously periodontally compromised and yet successfully treated patients after 3–84 months led to the conclusion that implants may successfully be incorporated into patients with a history of advanced periodontitis (Ellegaard et al. 1997), despite the fact that the survival rates reported appeared reduced when compared to previous reports on patients without a history of periodontal disease. In a longitudinal study of implants installed in patients previously affected with 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).

To date, no direct comparison of implant survival or success and complication rates has been provided in a controlled cohort study comparing both patients with and without a prior history of periodontal disease. Hence, there is no evidence to support a less favorable prognosis of dental implants installed in patients with a history of chronic periodontitis following successful periodontal therapy. In most longitudinal cohort studies in which survival and success rates of dental implants in partially edentulous patients were determined, there was no specification of the reasons of tooth extraction prior to implant placement. Therefore, the outcomes of these studies with respect to the longterm prognosis of implant therapy in patients with various risks for periodontal infection are still inconclusive.

Smoking has also been implicated as a risk factor to affect the long prognosis of oral implants. A significantly greater failure rate in smokers was reported when compared to

nonsmokers in a 6-year follow-up study (Bain & Moy 1993). In a prospective study (Bain 1996) thereafter, patients undergoing a successful smoking cessation protocol presented significantly higher implant-success rates compared to patients who continued smoking after implant placement. The detrimental effect on implant survival in the maxilla was also demonstrated by De Bruyn & Collaret (1994). More recently, smoking was identified to increase the risk of implant failure by a factor of 2.5 (Wilson & Nunn 1999). Cigarette smoking also influenced the prognosis of implants placed in grafted maxillary sinuses (Kan et al. 1999) and in augmented bone (Mayfield et al. 2001). Smoking was even associated as a major risk factor for multiple implant failure in a recent retrospective analysis (Ekfeldt et al. 2001).

The aims of the present prospective longitudinal cohort study were three-fold: (i) to compare survival, success and complication rates of implants placed in patients having lost their teeth due to chronic periodontitis to the rates found for implants placed in patients having lost their teeth due to other reasons (caries, fracture, anodontia, trauma); (ii) to calculate the success rates using a hierarchy of various thresholds set as success criteria, and (iii) to evaluate the influence of smoking on the long-term prognosis of oral implants.

Material and methods

Patients of a prospective, longitudinal, cohort study at the University of Berne School of Dental Medicine, Department of Periodontology and Fixed Prosthodontics, were recruited for a clinical and radiographic evaluation 10 years after implant installation. The patients had been treated for periodontal disease according to a comprehensive treatment strategy (Lang 1988) prior to the installation of implants and incorporation of suprastructures.

All the implants installed were hollow screw (HS) implants of the ITI[®] Dental Implant System (Institute Straumann AG, CH-4437, Waldenburg, Switzerland). They were placed according to the manufacturer's guidelines (Sutter et al. 1988). The suprastructures consisted of single crowns or fixed partial dentures (FPD), which were incorporated between 4 and 6 months postsurgically. Immediately after initial

periodontal therapy, the patients were offered supportive periodontal therapy (SPT), which was provided either in the Clinic for Periodontology and Fixed Prosthodontics, University of Berne, Switzerland, or in the dental practices of the referring dentists at intervals between 3 and 6 months.

At every recall examination during the 10-year follow-up period, all evident biological complications (peri-implantitis) were recorded and treated according to the implant maintenance and treatment protocol (Cumulative Interceptive Supportive Therapy – CIST) according to Lang et al. (2000).

Clinical examination

The same clinical and radiographic evaluations were performed at the 1-year baseline as well as at the 10-year examinations and included the following clinical parameters:

- modified plaque index (mPFI) (Mombelli et al. 1987) for all implants;
- modified bleeding index (mBFI) (Mombelli et al. 1987) for all implants;
- distance between the implant shoulder and the mucosal margin (DIM) in millimeters (recession scored as negative value);
- pocket probing depth (PPD) in millimeters;
- probing attachment level (PAL) in millimeters calculated by subtracting PPD from DIM;
- Bleeding on probing (BoP).

All measurements were performed at four aspects of each implant using a Hu-Friedy PGF-GFS periodontal probe (Hu-Friedy, Chicago, IL, USA). Distances were measured to the nearest millimeter.

Radiographic examination

Radiographs were obtained at 1 and 10 years of function, using a customized Rinn filmholder (XCP[®] Instruments, Rinn Corporation Elgin, IL, USA) with a rigid film-object-X-ray source coupling to a beam-aiming device in order to achieve reproducible exposure geometry. The radiographs 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

personal computer (Compaq 386/20, USA) and digitized with a frame grabber hardware card (Matrox Electronic Systems MVP/AT, Dorval Quebec, Canada). Using an image processing software, digitized images were stored with a resolution of (512 × 512 × 8)-bit pixels (256 shades of gray). These were displayed on a monitor, and linear measurements were performed with the help of a cursor.

All radiographic measurements were performed at the baseline (1 year) and the follow-up (10 years) radiographs by one calibrated examiner (I.K.). The distances in millimeters between the shoulder of the implant and the first clear bone-to-implant contact, mesially and distally, were noted. Changes in bone height over the entire observation period as well as annual rates of changes were calculated.

The criteria of success set for this study were chosen according to Karoussis et al. (2003), and included the following:

1. Absence of mobility (Buser et al. 1990).
2. Absence of persistent subjective complaints (pain, foreign body sensation and/or dysaesthesia) (Buser et al. 1990).
3. No PPD > 5 mm (Mombelli & Lang 1994; Brägger et al. 2001).
4. No PPD = 5 mm and BoP+ (Mombelli & Lang 1994).
5. Absence of a continuous radiolucency around the implant (Buser et al. 1990).
6. After the first year of service, the annual vertical bone loss should not exceed 0.2 mm (Albrektsson et al. 1986; Albrektsson & Isidor 1994).

According to this threshold, the implant was characterized as not successful (implant with a complication) if mesial or distal annual bone loss was > 0.2 mm, or PPD (even at one implant site) was > 5 mm or PPD (even at one implant site) = 5 mm with BoP+. 'Success' characterized an implant fulfilling both the clinical as well as the radiographic success criteria set (successful implant).

Another threshold tested did not include radiographic criteria: 'Clinical success' was defined as an implant fulfilling the clinical success criteria set (clinically successful implant). Furthermore, success rates were also calculated for less stringent thresholds, i.e. using a threshold of 6 mm instead of 5 mm for PPD. 'Success' then characterized an implant presenting no annual bone

loss > 0.2 mm mesially or distally, no site with PPD > 6 mm and no site with PPD = 6 mm and BoP+ (successful implant). 'Clinical success', again, characterized an implant fulfilling the clinical success criteria set (clinically successful implant).

Statistical analysis

Statistical analysis included descriptive statistics for all clinical and radiographic parameters assessed at implants and teeth, respectively. For the estimation of survival and incidence rates of peri-implantitis, a Kaplan–Meier analysis was used (Kaplan & Meier 1958). With life table statistics, the cumulative survival rates were calculated using the following formula (van Steenberghe et al. 1999):

$$CSR = \{PCSR + (ISR \times 100 - PCSR)\} / 100$$

where *R* is the rate, *C* the cumulative, *I* the interval, *P* the previous, and *S* the success. All implants that were not lost until the end of the observation period were considered according to the life table statistics as censored. By definition, incidence is the number of cases of a disease among the subjects of a population during a time period, divided by the sum of the length of time for each subject of the study population during which each subject is in danger of presenting the disease. All implants were in danger either until they were lost or until the end of the evaluation period (10 years).

During the observation period, all implant losses as well as the exact time until the failure had occurred were noted. Therefore, the survival time for each implant could be estimated accurately, since both implantation and explantation dates were available. The incidence rate may be calculated as follows:

$$\begin{aligned} \text{incidence rate } (I) \text{ for implant loss} \\ = \text{number of losses} / \Sigma \\ \text{(time in danger for each implant)}. \end{aligned}$$

Peri-implantitis was defined as an incidence of PPD ≥ 5 mm with BoP+ and radiographic signs of bone loss. For estimations of incidence rates of peri-implantitis, implants that were not affected until the end of the observation period were also considered as censored. After grouping into the patient groups (history – no history of chronic periodontitis as well as smokers and nonsmokers), the homogeneities of

survival curves, i.e. differences between the groups for the survival rates and incidences of peri-implantitis, were tested by log-rank test and Wilcoxon test.

χ^2 and Fisher's exact test were used to evaluate differences in the success rates between the implants of the patient groups. It should be mentioned that evaluation of success rates did not include only the surviving implants but all implants placed at the beginning of the study classifying failed implants as 'not successful'. Obviously, the exclusion of failed implants would increase any success rates and would lead to false interpretation of the actual situation. For comparison of the clinical parameters as well as bone loss mesially and distally, the Kruskal-Wallis test was used. The statistical tests were selected according to the requirements for the design of clinical trials in implant dentistry suggested at the 3rd European Workshop on Periodontology (Felechos et al. 1999). The data analyses were conducted by means of SAS statistical software (SAS Institute, Inc. 1999).

Results

A total of 53 patients with 112 hollow screw (HS) ITI® Dental Implants were evaluated. Sixty-seven of those implants were placed in women (59.8%), while 45 were placed in men (40.2%). Twenty-one implants were installed in eight patients with a history of chronic periodontitis, representing group A. The remaining 91 implants were installed in 45 patients without a history of chronic periodontitis replacing teeth lost due to other reasons such as caries, fractures, anodontia or trauma, representing group B.

Survival rates

The result of the Kaplan-Meier (1958) method (Fig. 1) showed that the survival rate for implants replacing teeth lost due to chronic periodontitis was 90.5% (SE: 0.064), while the survival rate for implants replacing teeth lost due to other reasons (caries, fracture, anodontia and trauma) was 96.5% (SE: 0.020) (Table 1).

The failure rate of group A was, therefore, 9.5%, while it was only 3.5% in group B. This difference however was not statis-

tically significant. The difference in survival rates became especially evident after the sixth year of service (Fig. 1).

Incidence of biological complications

The time period from implant installation until the occurrence of a biological complication or until the end of the evaluation period of 10 years was determined for all implants (Fig. 2).

71.4% (SE: 0.098) of the implants in patients belonging to group A remained free of any biological complication (peri-implantitis), while 94.2% (SE: 0.025) of the implants in patients belonging to group B did not present any biological complication over the 10-year evaluation period (Table 2).

The cumulative 10-year incidence of peri-implantitis was 28.6% for implants in patients of group A and 5.8% for implants in patients of group B. To test the homogeneity of the incidence curves, a significantly greater incidence of biological complications for implants placed in patients with a history of chronic periodontitis following therapy was demonstrated when compared to patients without such a history (log-rank test: $P = 0.0002$; Wilcoxon test: $P = 0.0001$).

Success rates

The overall success and clinical success rates of the implants in patients belonging to the two groups are presented in Table 3 and Fig. 3.

With the success criteria set (PPD ≤ 5 mm and BoP—as well as bone loss < 0.2 mm annually), success rates of 52.4% and 79.1% for implants replacing teeth lost due to periodontitis and for implants replacing teeth lost due to other reasons, respectively, were found (Fisher's exact test: $P < 0.025$).

Relying on clinical parameters only (PPD ≤ 5 mm and BoP—), the success rates were 71.4% and 94.5% for groups A and B, respectively (Fisher's exact test: $P < 0.006$). If the definition of success criteria included a threshold of 6 mm instead of 5 mm for PPD, the success rates in percentages is listed in Table 4 and Fig. 3.

With these success criteria, a success rates of 62% for group A and of 81.3% for group B were found. This difference, however, was not statistically significant. Again, relying on clinical parameters only (PPD ≤ 6 mm and BoP—), success rates were elevated to 81% and 96.7% for groups A and B, respectively (Fisher's exact test: $P < 0.023$).

Table 5 lists the means and standard deviations of the clinical and radiographical parameters assessed for implants belonging to both groups.

Effect of smoking

In patients of group A, 47.6% of the implants were installed in smokers, while only 19.78% of the implants in patients of group B were installed in smokers. After stratification for smoking, 84 implants were placed in 41 nonsmokers and 28 were placed in 12 smokers. Table 6 lists survival

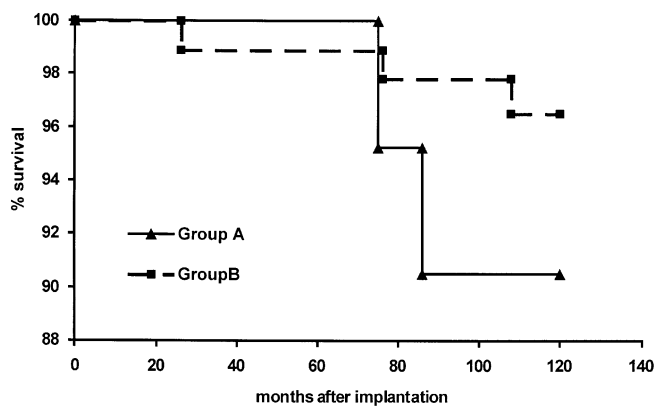


Fig. 1. Kaplan-Meier estimate of survival rates of implants, placed in patients with or without a history of periodontitis, as a function of time since insertion. Group A: patients with a history of periodontitis; group B: patients without a history of periodontitis.

rates, incidences of biological complications and success rates as well as the statistical methods applied. The homogeneity of the survival curves was tested with the Wilcoxon test. Overall success and clinical success rates were calculated, and Fisher's exact test was used to indicate any significant differences. As demonstrated in Table 6, no significant differences were found for any of the parameters mentioned.

Further evaluation on the results of the present study included stratification for smoking in both patients with and without a history of periodontitis. Table 7 lists survival rates, incidences of biological

complications and success rates as well as the statistical methods used for evaluation of any differences. Among implants placed in nonsmokers, implants replacing teeth lost due to periodontitis presented significantly higher incidences of biological complications ($P < 0.017$). 'Success' as well as 'clinical success' rates in nonsmokers seemed to be lower for implants placed in patients with a history of periodontal disease (54.55% vs. 80.82% and 81.85% vs. 94.52%, respectively). These differences, however, did not reach statistical significance.

Table 8 lists survival rates, incidences of biological complications and success rates

as well as the statistical methods used for the evaluation of any differences between implants placed in smokers and stratified according to history of periodontitis.

For smokers, implants replacing teeth lost due to periodontitis presented significantly higher incidences of biological complications ($P < 0.024$). 'Success' rates seemed to be lower for implants placed in patients with a history of periodontal disease (50% vs. 72.22%) as well, but this difference did not reach statistical significance. 'Clinical success' rates were significantly lower for implants placed in smokers with a history of periodontal disease than in smokers without such a history ($P < 0.041$). Survival for implants placed in smokers was lower for implants placed in smokers with a history of periodontitis as well. The Wilcoxon test showed a tendency for this difference to be significant ($P < 0.052$).

Finally, the differences between implants placed in smokers and in nonsmokers were calculated for groups A and B, respectively. For both groups, no significant differences for the parameters evaluated were found between implants placed in smokers or in nonsmokers (Tables 9 and 10).

Table 1 Survival and failure rates of implants over 10 years in patients with (group A) or without (group B) a history of periodontitis

Group	Implants placed	Implants lost	Survival (%)	Failure (%)	Standard error
A	21	2	90.5	9.5	0.064
B	91	3	96.5	3.5	0.020

Group A: patients with a history of periodontitis; group B: patients without a history of periodontitis.

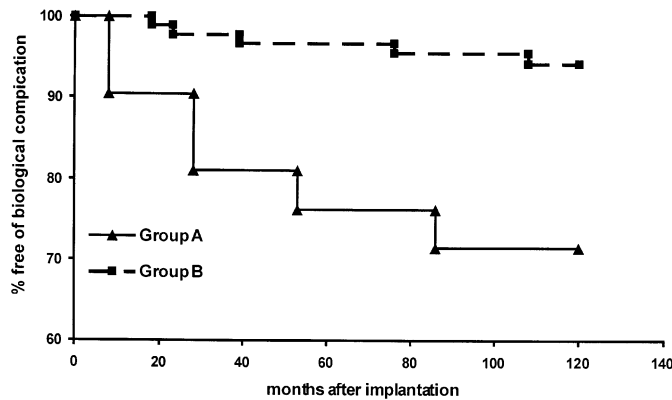


Fig. 2. Kaplan-Meier estimate of incidence of biological complication (peri-implantitis) in patients with or without a history of periodontitis as a function of time since insertion. Group A: patients with a history of periodontitis; group B: patients without a history of periodontitis.

Table 2 Incidence of biological complication over 10 years in implants placed in patients with or without a history of periodontitis

Group	Implants placed	Implants with complications	Complication-free implants (%)	Incidence of complication (%)	Standard error
A	21	8	71.4*	28.6*	0.098
B	91	5	94.2	5.8	0.025

*The incidence of biological complications (peri-implantitis) was significantly higher for implants placed in patients with a history of chronic periodontitis than for implants placed in patients without (Wilcoxon test, $P = 0.0001$, log-rank test, $P = 0.0002$). Group A: patients with a history of periodontitis; group B: patients without a history of periodontitis.

Discussion

The present study has demonstrated that osseointegrated implants replacing teeth lost due to chronic periodontitis demonstrated lower survival rates than oral implants replacing teeth lost due to caries, trauma or agenesis. In this respect the study supports the hypothesis that an increased susceptibility for periodontitis may, indeed, also translate to an increased susceptibility for peri-implantitis and implant loss. The present study also demonstrated that patients previously suffering from, and successfully treated for, chronic periodontitis experienced a significantly higher incidence of peri-implantitis and significantly lower success rates of their implants after 10 years of service than patients without a history for periodontitis. Although several case series (Malmstrom et al. 1990; Fardal et al. 1999) have expressed the notion for higher susceptibility for peri-implantitis in patients with a history of periodontitis, when compared to patients without such a history, there is limited evidence based on prospective studies to support such a

Table 3 Success rates over 10 years using 5 mm as borderline for PPD and annual bone loss <0.2 mm, clinical success meaning that the implant fulfilled the clinical criteria

Group	Implants placed	Success	Clinical success
A	21	11 (52.4%)*	15 (71.4%)*
B	91	72 (79.1%)	86 (94.5%)

*Implants placed in previously periodontally compromised patients demonstrated statistically significantly lower success rates than implants placed in patients having lost their teeth due to reasons other than periodontitis (Fisher's exact test for success: $P < 0.025$; for clinical success: $P < 0.006$).

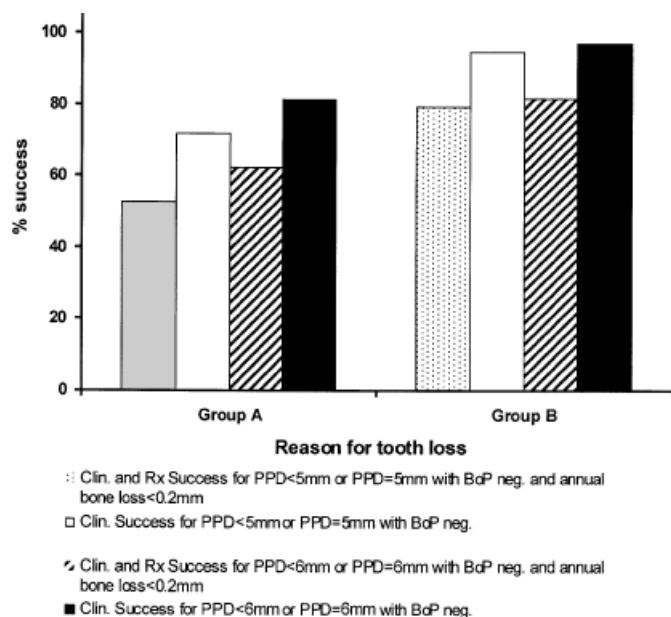


Fig. 3. Success rates of ITI® Dental Implants placed in previously periodontally compromised patients (group A) and previously periodontally noncompromised patients (group B), applying different criteria for the definition of 'success'.

Table 4 Success rates over 10 years using 6 mm as borderline for PPD and annual bone loss <0.2 mm, clinical success meaning that the implant fulfilled the clinical criteria

Group	Implants placed	Success	Clinical success
A	21	13 (62%)	17 (81%)*
B	91	74 (81.3%)	88 (96.7%)

*Implants placed in previously periodontally compromised patients demonstrated statistically significantly lower clinical success rates than implants placed in patients having lost their teeth due to reasons other than periodontitis (Fisher's exact test: $P < 0.023$).

hypothesis. One prospective longitudinal study compared the survival and success rates of two different implant systems in a patient cohort of a specialist private practice (Ellegaard et al. 1997). All the patients involved had a documented history of advanced chronic periodontitis. Prior to implant installation, the patients had undergone periodontal therapy including sur-

gery to eliminate all pathologically deepened pockets. Subsequently, the patients who were able to maintain high standards of oral hygiene were involved in a carefully monitored maintenance care program and followed up to 84 months. Comparing the Kaplan-Meier estimate of the ITI® Dental Implant System surviving 5 years (Ellegaard et al. 1997) with the

survival estimate of 5 years in the present study reveals a 2.7% and 7.7% difference for the maxillary and mandibular implants, respectively in favor of the results of the present study. These survival estimates may provide only limited information on the longevity of implant systems mainly because implant losses appear to be rare in the first 5 years of observation. Although the survival rate of the implants in patients with a history of chronic periodontitis was 100% up to 6 years of service in the present study, it decreased dramatically between 6 and 8 years and reached a cumulative survival rate of 90.5% at 10 years. This, in turn, means that a higher susceptibility for the loss of implants in patients with a history of periodontitis compared to patients with no such history may first become evident after prolonged observation periods of 5–10 years. Implant loss may be the result of multiple episodes of peri-implant infections (Lindhe et al. 1992; Lang et al. 1993; Schou et al. 1993) and, hence, the incidences of peri-implantitis in populations with a history of periodontitis may also be significantly higher than in patients without such a history. In fact, the results of the present study clearly documented these differences. Depending on the threshold chosen for the definition of peri-implantitis (e.g. PPD ≥ 5 mm and BoP+), the cumulative incidence of peri-implantitis was 28.6% and 5.8% for patients with and without a history of periodontitis, respectively. The former value was even substantially better than using similar thresholds for PPD in the study of the ITI implants placed in patients with a history of chronic periodontitis in Denmark (Ellegaard et al. 1997), in which the cumulative incidence of PPD ≥ 6 mm reached values of 30.5% already after 5 years. After 10 years, the success rate defined as PPD < 6 mm and BoP– was 71.4% and 94.5% in patients with or without a history of periodontitis of the present study, respectively. Hence, it appears from both prospective studies using patient cohorts with a history of periodontitis that the risk for biological complications of peri-implant tissues eventually leading to implant loss is substantially elevated when compared to the patient cohorts normally incorporated in prospective longitudinal studies on implant

Table 5 Means, standard deviation (SD) and statistical test results (Kruskal–Wallis test) of clinical and radiographic parameters measured for each implant

	Group A, n = 21 (8 patients)		Group B, n = 91 (45 patients)	
	Mean	SD	Mean	SD
mPll mean	0.47	0.51	0.33	0.38
mBll mean	0.28	0.44	0.16	0.24
PPD mean	3.03	1.58	2.52	0.64
PAL mean	-3.59	1.40	-3.12	0.72
BoP mean	0.29	0.36	0.40	0.33
ΔBone loss mes	1.00	1.38	0.48	1.10
ΔBone loss dist	0.94	0.73	0.50	1.08

Table 6 Survival, incidence of biological complication, success and clinical success rates for implants placed in smokers or in nonsmokers

	Implants placed in smokers n = 28		Implants placed in nonsmokers n = 84		Statistical test	Significance
	Number	%	Number	%		
	Survival	26	92.86	81		
Incidence of biological complication	5	17.86	8	6.02	Kaplan–Meier Wilcoxon test	NS
Success	18	64.29	65	77.38	Fisher’s exact test	NS
Clinical success	23	82.14	78	92.86	Fisher’s exact test	NS

NS: not significant.

Table 7 Survival, incidence of biological complication, success and clinical success rates for implants placed in patients with a history of periodontitis (implants belonging to patients of group A) and for implants placed in patients without a history of periodontitis (implants belonging to patients of group B); this grouping included only implants placed in nonsmokers

	Implants in patients of group A, n = 11		Implants in patients of group B, n = 73		Statistical test	Significance
	Number	%	Number	%		
	Survival	11	100	70		
Incidence of biological complication	4	18.18	4	5.8	Kaplan–Meier Wilcoxon test	P < 0.017
Success	6	54.55	59	80.82	Fisher’s exact test	NS
Clinical success	9	81.82	69	94.52	Fisher’s exact test	NS

NS: not significant.

survival in the partially edentulous patients (Buser et al. 1999).

The reason for higher susceptibility to biological complications around implants in patients with a history of periodontitis compared to those without such a history may be discussed in the light of either bacterial plaque accumulation in partially edentulous dentitions or the host response to the bacterial challenge. Both aspects may vary when compared to patients who lost their teeth for reasons

other than chronic or aggressive periodontitis.

Microbiological studies in partially edentulous patients (Mombelli et al. 1995) have demonstrated that 3–6 months following the placement of nonsubmerged and submerged implants after abutment connection, a similar proportion of presumptive pathogens was found at both implants and the deepest periodontal pockets in each quadrant of the dentition. Also it was demonstrated that periodontal pathogens

recognized prior to implant placement in residual periodontal pockets of the remaining dentition represented sources of infection for the subsequent bacterial colonization of newly installed sterile implants (Mombelli et al. 1995). Furthermore, it was documented in a cross-sectional study of patients with a history of periodontal disease (Leonhardt et al. 1993) that the composition of the microbiota around remaining teeth was reflected in the composition of the peri-implant microbiota. Also, the similarity in the microbiota associated with periodontitis and peri-implantitis supports the concept that periodontal pathogens are important etiological factors for peri-implant infections (Mombelli et al. 1987; Leonhardt et al. 1992; Mombelli & Lang 1992). It is therefore obvious that the status of health reached following successful periodontal therapy is of utmost importance for the longevity of implants installed.

In the present study, all the patients were incorporated in an individually designed maintenance care program, with regular visits to the dental hygienists at intervals of 3–8 months depending on the risk for periodontal reinfection determined by the mean individual BoP percentage and the presence of residual pockets. Despite this structured maintenance program, the patient group with a history of periodontitis being recalled usually at 3–5-month intervals experienced significantly more frequent episodes of peri-implantitis than the patient group without a history for periodontal disease and, hence, not having been recalled more frequently than 4–8 months.

Recently, several studies have been undertaken to determine risk factors for peri-implant bone loss such as, e.g. genetic markers. From the patient cohort followed in the present study, interleukin-1 gene polymorphisms were determined and compared to the annual rate of bone loss in periodontally susceptible patients (Feloutzis et al. 2003). These studies revealed that IL-1 genotype positive smoking patients yield a higher risk for peri-implant bone loss than IL-1 negative smokers. Heavy smoking patients also significantly demonstrated higher rates of peri-implant alveolar bone loss than nonsmokers.

Smoking as a confounding factor was also analyzed in the present study. In patients with a history of periodontitis, 47.6% of the implants were placed in heavy smokers,

Table 8 Survival, incidence of biological complication, success and clinical success rates for implants placed in patients with a history of periodontitis (group A) and for implants placed in patients without a history of periodontitis (group B); this grouping included only implants placed in smokers

	Implants in patients of group A, n = 10		Implants in patients of group B, n = 18		Statistical test	Significance
	Number	%	Number	%		
Survival	8	80	18	100	Kaplan–Meier Wilcoxon test	P < 0.052
Incidence of biological complication	4	40	1	5.56	Kaplan–Meier Wilcoxon test	P < 0.024
Success	5	50	13	72.22	Fisher’s exact test	NS
Clinical success	6	60	17	94.44	Fisher’s exact test	P < 0.041

NS: not significant.

Table 9. Survival, incidence of biological complication, success and clinical success rates for implants placed in smokers or nonsmokers with a history of periodontitis (group A)

	Implants in smokers, n = 10		Implants in nonsmokers, n = 11		Statistical test	Significance
	Number	%	Number	%		
Survival	8	80	11	100	Kaplan–Meier Wilcoxon test	NS
Incidence of biological complication	4	40	4	36.36	Kaplan–Meier Wilcoxon test	NS
Success	5	50	6	54	Fisher’s exact test	NS
Clinical success	6	60	9	81.82	Fisher’s exact test	NS

NS: not significant.

Table 10. Survival, incidence of biological complication, success and clinical success rates for implants placed in smokers or nonsmokers without a history of periodontitis (group B)

	Implants in smokers, n = 18		Implants in nonsmokers, n = 73		Statistical test	Significance
	Number	%	Number	%		
Survival	18	100	70	95.7	Kaplan–Meier Wilcoxon test	NS
Incidence of biological complication	1	5.56	4	5.79	Kaplan–Meier Wilcoxon test	NS
Success	13	72.2	59	80.82	Fisher’s exact test	NS
Clinical success	17	94.4	69	94.5	Fisher’s exact test	NS

NS: not significant.

while only 19.8% of the implants were placed in heavily smoking patients without a history of periodontitis. However, owing to the small numbers of subjects followed over 10 years in the present study the differences in either survival, incidence rates of biological complications or success rates between smokers and nonsmokers in both patient groups with and without a history of periodontitis did not reach

statistical significance. However, there was a tendency for a poorer survival rate of implants in smokers vs. nonsmokers (80% vs. 100%) in patients with a history of periodontitis, indicating that the smoking patient susceptible to periodontitis yields a documented higher risk for implant loss than the non-smoking periodontitis patient or the patient not susceptible to periodontitis at all.

The results of the present study do not agree with previously published reports on machined root formed implants observed for 1–8 years (Nevins & Langer 1993, 1995). In these reports a successful use of osseointegrated implants in patients with a history of periodontal disease was postulated. Despite the fact that several patients had lost peri-implant bone beyond the usual level expected for this particular implant system within the first year, no comparison to a control group without a history of periodontitis was made and, hence, statements regarding susceptibility for peri-implant biological complications, or implant failure of specific patient groups such as those with a history of periodontitis are not appropriate. Other studies in periodontally compromised patients without a control group reported similar lower cumulative success rates for patients in periodontal maintenance corresponding to the findings of the present study (Brocard et al. 2000). The results of the present study are also in contrast with those reported by Quirynen et al. (2001). In this study the rate of bone loss around screw-shaped implants with machined surfaces was not influenced by the progression rate of periodontal destruction around the remaining teeth. Therefore, it was concluded that ongoing periodontitis does not imply an increased chance for peri-implantitis. The survival rate over a mean of 5 years varying from 3 to 11 years, however, was 95.8%. No signs of peri-implantitis such as probing depths or BoP were reported, however. As mentioned before, studies of a duration of less than 5–10 years may not yield differences in susceptibility to peri-implant bone loss, biological complications or implant loss in patients with or without a history of periodontitis. Furthermore, no statements regarding such susceptibility should be made if patients with a history of periodontitis cannot be compared to control cohorts.

In conclusion, this prospective longitudinal 10-year cohort study (8–12 years) has demonstrated that oral implants may successfully be placed and maintained in patients with and without a history of periodontitis. However, patients with a history of periodontitis yielded lower survival (90.5% vs. 96.5%), significantly higher complication (28.6% vs. 5.8%) and significantly lower success rates

(e.g. 71.4% vs. 94.5%) than patients who had lost their teeth for reasons other than periodontitis.

Furthermore, the study has demonstrated that success rates are highly dependent on the success criteria defined. Hence, in comparing various studies it has to be realized that comparable success criteria are a necessity for reasonable interpretation of study results.

Acknowledgments: This study was supported by the Clinical Research Foundation (CRF) for the Promotion of Oral Health, University of Berne, Berne, Switzerland and by the Papavramides Foundation, Universities of Athens, Greece and Berne, Switzerland. The senior author is the recipient of an ITI-Fellowship for 2001–2002.

Résumé

Le but de cette étude de dix années a été de comparer les taux d'échecs, de succès et de complications d'implants entre les patients ayant perdu leurs dents dû à la parodontite ou pour d'autres raisons. Cinquante-trois patients qui ont reçu 112 implants vis creux (HS) du système ITI ont été divisés en deux groupes: groupe A, huit patients avec 21 implants qui avaient perdu leurs dents suite à la parodontite chronique et, groupe B, 45 patients avec 91 implants sans passé de parodontite. Une et dix années après le placement chirurgical, des paramètres cliniques et radiographiques ont été relevés. Les incidences de la paroiimplantite ont été notées durant les dix ans de traitement parodontal de rappel. Les critères de succès à dix ans étaient $PPD \leq 5$ mm, BOP négatif, perte osseuse $< 0,2$ mm/an. Le taux de survie pour le groupe avec un passé de parodontite était de 90,5% tandis que dans celui sans passé de parodontite il était de 96,5%. Le groupe A avait une incidence plus importante de paroiimplantite que le groupe B (28,6% vs 5,8%). Avec les trois critères de succès, 52,4% des implants du groupe A et 79,1% de ceux du groupe B avaient été placés avec succès. Avec le seuil de $PPD \leq 6$ mm, le BOP négatif et une perte osseuse $< 0,2$ mm/an les taux de succès s'élevaient respectivement à 62 et 81,3% pour les groupes A et B. En tenant compte uniquement des paramètres cliniques de $PPD \leq 5$ mm et d'absence de BOP, les taux de succès étaient de 71,4 et 94,5%; avec un seuil placé pour le $PPD \leq 6$ mm et absence de BOP, ces proportions s'élevaient à 81 et 96,7%. Les patients ayant des implants pour remplacer des dents perdues à cause de la parodontite avaient donc des taux de survie inférieurs et davantage de complications biologiques que les patients avec des implants placés en remplacement de dents perdues pour d'autres raisons. De plus, le choix des seuils pour les critères de succès est extrêmement important pour tirer toute conclusion.

Zusammenfassung

Ziel: Das Ziel dieser Studie über 10 Jahre war es, die Misserfolgs-, Erfolgs- und Komplikationsrate zwischen Patienten, welche ihre Zähne wegen Parodontitis oder aus anderen Gründen verloren haben, zu vergleichen.

Material und Methoden: 53 Patienten, bei welchen 112 Hohlschraubenimplantate (HS) des ITI® Dental Implant Systems eingegliedert worden waren, wurden in 2 Gruppen aufgeteilt: Gruppe A: 8 Patienten mit 21 Implantaten, welche ihre Zähne wegen chronischer Parodontitis verloren hatten und Gruppe B: 45 Patienten mit 91 Implantaten ohne vorbestehende Parodontitis. Ein und zehn Jahre nach dem chirurgischen Eingriff zum Setzen der Implantate wurden klinische und radiologische Parameter aufgenommen. Das Auftreten einer Periimplantitis wurde während der regelmässigen, 10 Jahre dauernden, unterstützenden Parodontaltherapie aufgezeichnet.

Resultate: Als Erfolgskriterien nach 10 Jahren wurden festgelegt: $PPD \leq 5$ mm, BOP-, Knochenverlust $< 0,2$ mm pro Jahr. Die Überlebensrate bei der Gruppe mit vorbestehender chronischer Parodontitis (Gruppe A) betrug 90,5%, während sie für die Gruppe ohne vorbestehende Parodontitis (Gruppe B) 96,5% betrug. Bei Gruppe A traten signifikant häufiger Probleme mit Periimplantitis auf als bei Gruppe B (28,6% gegenüber 5,8%). Gemessen an den gesetzten Erfolgskriterien waren in der Gruppe A 52,4% und in Gruppe B 79,1% der Implantate erfolgreich. Mit den Schwellenwerten $PPD \leq 6$ mm, BOP- und Knochenverlust $< 0,2$ mm pro Jahr erhöhten sich die Erfolgsraten für Gruppe A auf 62% und für Gruppe B auf 81,3%. Wenn nur die rein klinischen Parameter $PPD \leq 5$ mm und BOP- in Betracht gezogen wurden, betrugen die Erfolgsraten 71,4% für Gruppe A und 94,5% für Gruppe B. Mit klinischen Schwellenwerten $PPD \leq 6$ mm und BOP- erhöhten sich die Erfolgsraten auf 81% für Gruppe A bzw. 96,7% für Gruppe B.

Schlussfolgerungen: Patienten mit Implantaten als Folge von Zahnverlust durch chronische Parodontitis zeigen über einen Zeitraum von 10 Jahren tiefere Erfolgsraten und mehr biologische Komplikationen als Patienten mit Implantaten als Folge von Zahnverlust durch andere Gründe als Parodontitis.

Resumen

Intención: La intención de este estudio de 10 años fue comparar los índices de fracaso, de éxito y de complicaciones entre pacientes que perdieron sus dientes debido a periodontitis u otras razones, respectivamente.

Material y Métodos: 53 pacientes que recibieron 112 implantes roscados huecos (HS) del Sistema de Implantes Dentales ITI® se dividieron en dos grupos: Grupo A: 8 pacientes con 21 implantes que perdieron sus dientes debido a periodontitis crónica y grupo B: 45 pacientes con 91 implantes sin una historia de periodontitis. Se valoraron parámetros clínicos y radiográficos uno y diez años tras la colocación quirúrgica. Las incidencias de peri-implantitis se registraron a lo largo de los 10 años de tratamiento periodontal de mantenimiento.

Resultados: Los criterios de éxito a los 10 años se situaron en: $PPD \leq 5$ mm, BOP-, pérdida ósea $< 0,2$ mm por año. El índice de éxito para el grupo con una historia pasada de periodontitis crónica (Grupo A) fue del 90,5%, mientras que sin historia anterior de periodontitis (Grupo B) fue del 96,5%. El Grupo A tuvo una incidencia significativamente mayor de peri-implantitis que el Grupo B (28,6% vs. 5,8%). Con el criterio de éxito fijado, el 52,4% de los implantes del Grupo A y el 79,1% del Grupo B tuvieron éxito. Con un umbral fijado en $PPD \leq 6$ mm, BOP -y pérdida ósea $< 0,2$ mm por año, los índices de éxito se elevaron hasta el 62% y 81,3% para los grupos A y B respectivamente. Recayendo puramente en los parámetros clínicos de $PPD \leq 5$ mm y BOP-, los índices de éxito fueron del 71,4% y 94,5%, y con un umbral situado en $PPD \leq 6$ mm y BOP-, las proporciones se elevaron al 81% y 96,7% para los grupos A y B respectivamente.

Conclusiones: Los pacientes con implantes sustituyendo a dientes perdidos por periodontitis crónica demostraron unos índices de supervivencia mas bajos y mas complicaciones biológicas que los pacientes con implantes sustituyendo a dientes perdidos por otras razones que la periodontitis durante un periodo de 10 años de mantenimiento. Mas aun, la fijación de los criterios de éxito es crucial para informar los índices de éxito.

要旨

目的: この10年間の研究は、歯周炎による歯牙喪失患者と他の理由による歯牙喪失患者の間でインプラントの失敗率、成功率と合併症率を比較することを目的に行った。

材料と方法: ITI® インプラント・システムの中空スクリュー・インプラント (HS) 112本を埋入した53名の患者を以下の2群に分けた; グループA: 慢性歯周炎により歯牙を喪失した患者8名で、21本のインプラントを入れた。グループB: 歯周炎の既往のない患者45名で、91本のインプラントを入れた。インプラント埋入術後1年後と10年後に、臨床的及びX線上のパラメータを評価した。定期的な歯周維持療法を行った10年間のインプラント周囲炎の発症率を調べた。結果: 10年後の成功基準は、 $PPD \leq 5$ mm、BOP及び1年あたりの骨喪失量 $< 0,2$ mmと設定した。慢性歯周炎の既往有りの群 (グループA) のインプラント生存率は90,5%であり、歯周炎の既往無しの群 (グループB) は96,5%であった。グループAはBよりもインプラント周囲炎の発症率が有意に高かった(28,6%対5,8%)。上述の成功基準に基づく、グループAの成功率は52,4%、グループBは79,1%であった。 $PPD \leq 6$ mm、BOP及び1年あたりの骨喪失量 $< 0,2$ mmという閾値によると、グループAとBの成功率は各々62%と81,3%となった。 $PPD \leq 5$ mmとBOPという臨床的パラメータのみに基づく、成功率は各々71,4%と94,5%であり、 $PPD \leq 6$ mmとBOPという閾値では、グループAとBの成功率は各々81%と96,7%に上昇した。

結論: 10年のメンテナンス期間中に、慢性歯周炎によって歯牙を失った患者のインプラントは、歯周炎以外の理由で歯牙を失った患者のインプラントよりも、生存率が低く、生物学的な合併症率も高かった。さらに成功基準の閾値の設定は、成功率の報告に非常に重大な影響を及ぼすものである。

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