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ORIGINAL ARTICLE

Effect of periodontitis history on implant success: a long-term evaluation during supportive periodontal therapy in a university setting

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Abstract
Objectives The aim of this retrospective study was to evaluate the long-term implant survival in patients with a history of chronic periodontitis, during supportive periodontal therapy (SPT), compared to periodontally healthy patients.
Materials and methods Twenty-nine periodontitis patients (test) with SPT for ≥9 years and implant-supported restorations (≥5 years follow-up) were recruited and pair-matched with 29 periodontally healthy patients (control). Subjects in both groups were examined following active periodontal therapy and/or implantation (T1) (test 69 implants, control 76 implants) and at end of SPT or supportive postimplant therapy (T2). Differences between the groups in implant survival (primary outcome), mean marginal bone loss (MBL) and pocket probing depths (PPDs) (secondary outcomes) were evaluated.
Results Implant survival over 5 years was 97.1% in test compared to 97.4% in control group ($p = 0.562$). MBL was significantly different (test 18.7 ± 18.2%; control 12.5 ± 21.3%) ($p < 0.05$). PPDs increased at T2 in both groups (test: T1 3.4 ± 1.0 mm; T2 4.2 ± 1.6 mm; control: T1 1.0 ± 1.2 mm; T2 2.9 ± 0.8 mm; $p < 0.05$ between groups). Prognostic factors for implant loss appeared to be the presence of residual periodontal pockets of ≥4 mm (OR 1.90), bone height (OR 1.81) and age (OR 1.16) at T1.
Conclusion In terms of implant survival, no differences were observed between periodontitis and periodontally healthy patients. However, patients with history of periodontitis showed higher MBL and PPDs compared to periodontally healthy patients.
Clinical relevance The presence of a good periodontal maintenance program with preceding successful active periodontal treatment seems to be indispensable components of successful implant treatment in patients with history of chronic periodontitis.

Keywords Implant loss · Periodontitis · Bone loss · Supportive periodontal therapy · Risk factors

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Introduction

Periodontitis is a bacterially induced chronic inflammatory disease affecting the periodontium surrounding and supporting the teeth [1]. Untreated, periodontitis is branded by a progressive clinical attachment loss with advanced alveolar bone destruction and constitutes the major cause of tooth loss worldwide [2]. In replacing lost teeth, the clinical use of oral implants has become integral to comprehensive dental care [3]. The primary advantage of their use lies primarily in the preservation of the adjacent natural tooth structure, usually sacrificed to anchor fixed dental prostheses [4], unaffected and the avoidance of unilateral free-end situations with inadequate functional occlusion [5, 6]. In an endeavour to reduce implant failure rates, more attention is being directed to understand the aetiology and the risk factors that underlie their failure [7].

Although aiming successful retention of periodontally diseased teeth in terms of a reasonably priced and effective treatment compared to their extraction and replacement by dental implants [6, 8, 9], certain clinical conditions lead to the necessity of endosteal dental implants. Concomitant with the increasing amount of placed dental implants, inflammations of peri-implant tissues are increasing and becoming a global burden [10]. Studies on patients with a history of treated chronic periodontitis indicate a higher incidence of biological complications and lower dental implant success/survival rates, compared to implants in periodontally healthy patients [11–13]. Apart from the higher incidence of implant loss reported [14, 15], when periodontal as well as implant maintenance programs were provided, implant failure rates seemed to be low independent of the presence of a history of treated periodontitis [10, 16]. A significantly lower implant survival rate was recently reported for patients with history of aggressive periodontitis [17, 18]. In the presence of a history of chronic periodontitis, there is still a disagreement about the extent of biological complications, including marginal bone loss (MBL) or probing pocket depths (PPDs) and rate of implant loss [13, 19, 20]. Therefore, the aim of the current longitudinal study was to investigate the survival of dental implants replacing missing teeth in patients treated for chronic periodontitis over more than 5 years of SPT in a university setting. Primary outcome was implant survival. Secondary parameters investigated were the mean MBL and PPD around the dental implants.

Material and methods

Study population

In the present study, 29 compliant patients diagnosed with chronic periodontitis (CP) with dental implants inserted after active periodontal treatment phase (APT) were enrolled. The current study presents the fifth part of a longitudinal retrospective clinical cohort study based on demographic, radiographic and clinical data. Between the years 1982 and 1998, 2564 patients were treated for periodontitis at the Department of Periodontology, Christian-Albrechts-University of Kiel, Germany. Only patients who had received SPT for ≥9 years with ≥1 visit/year, including an annual documentation of PPD as well as a complete radiographic documentation at the beginning of the periodontal treatment (T0) and at the last documented visit of SPT (T2) were included in the current study. A total of 1877 patients did not fulfil the criterion of ≥9 years of regular SPT and a complete annual documentation of all variables. The periodontal diagnosis as well as the severity was classified according to Armitage [21], whereas only patients with chronic periodontitis were included (exclusion of 239 patients with aggressive periodontitis). Further, 102 patients had incomplete clinical or radiographic documentation, and from 31 patients, radiographs were not evaluable. A total of 315 patients fulfilled the mentioned inclusion criteria, and from this cohort, 54 patients had dental implants inserted for ≥5 years during the follow-up period (exclusion 235 patients without documentation of implants; 26 patients with implants ≤5 years of follow-up period). Furthermore, 24 patients had no radiographic documentation at implant insertion (T1) and one patient, who lost all implants after resection surgery of the lower jaw during cancer treatment, was excluded. Therefore, 29 patients were included in the test group. For the current investigation, additionally, a second "control" group of periodontally healthy patients (not diagnosed with periodontitis) was recruited from the Department of Oral-, Maxillofacial and Plastic Surgery, Christian-Albrechts-University of Kiel, Germany. Using the criteria, age, gender, number of teeth and time of follow-up after implant insertion, 29 periodontally healthy patients were matched. For the control group, complete radiographic documentation and periodontal records at baseline T1 (implant insertion) and at the final documented visit (T2) were a prerequisite.

For further details regarding the recruitment of the test group, see Graetz et al. [22, 23].

PPD and radiographic assessment of MBL

The annual maximum PPDs of six measured values per tooth and implant were extracted (A.G.). Third molars were excluded. The reproducibility of the data entry was verified by a second investigator (A.P.). Plots were generated to compare the progression of PPD between test and control group patients.

For radiographic evaluation at T1 and T2, radiographs (parallel or panoramic technique) of the 58 patients were digitized and analysed (A.G.) (ImageJ, NIH, Bethesda, MD, USA). To calculate MBL, the radiographic linear distance from implant shoulder to the first bone-implant contact and the apex parallel to each implant surface was marked and expressed as percentages of the total implant length. A.G. was calibrated before the beginning of the radiographic evaluation from an experienced operator (E.B.). The reproducibility was verified by assessment of pivotal landmarks. The inter-rater reliability between both examiners was $\kappa_w = 0.801$.

Tooth/implant loss during observation time

Implant and tooth loss during the observation time (T1–T2) were documented.

Periodontal treatment and prosthetic rehabilitation (test group)

All patients of the test group received similar periodontal treatment, comprised of deep scaling and root planning (SRP).

Residual probing pocket depths (PPDs) and furcation involvement (FI) were re-evaluated after 3–6 months. If PPD was ≥6 mm with signs of inflammation including bleeding on probing (BOP) and/or molars with advanced FI (degree II and III), additional access flap surgery (OFS) for root debridement was performed. No pocket elimination surgery or osseous resections were attempted.

SPT (T1-T2) was performed within individualized intervals. If indicated (PPD ≥4 mm + BOP or PPD ≥5 mm without BOP), either non-surgical SRP or open flap debridement with or without subsequent systemic or local antibiotic therapy was performed.

If prosthetic therapy was necessary, fixed or removable dental prostheses were fabricated after APT at T1, as reported by Graetz et al. [6], including the insertion of dental implants.

Implant treatment and prosthetic rehabilitation (test and control group)

According to the investigation by Frisch et al. [24] with a comparable treatment concept, the high relevance of a postimplant maintenance care program for the future prevention of peri-implant disease has been explained to all patients. Following implants' placement according to the manufacturers' protocols and the insertion of the implant-supported prostheses (healing periods of 3–6 months), a systematic supportive postimplant therapy (SIT) was initiated [25]. During the observation period, changes in experienced operators, prosthesis design, material selection, or technical procedures were made. Following the delivery of the implant-supported prostheses, patients received oral hygiene instructions and were scheduled for a postoperative implant maintenance program with 3–6 months follow-up.

Data managing and statistical analysis

Data extraction was performed independently by two investigators (E.B., C.G.) and consensus obtained by consulting a third one (A.G.). Statistical evaluation was performed blinded and independently (A.P.).

The implant was taken as the unit of analysis. Periodontal parameters: PPD (in mm), radiological MBL (in % of the implant length), tooth loss (yes/no), implant loss (yes/no), periodontal treatment for each tooth (yes/no), medical history (diabetes and coronary heart disease) and smoking status, were evaluated. According to self-reported smoking history, patients were categorized into "never smokers", who had never smoked in their lives, "former smokers", who had quit smoking continuously for at least 5 years backwards, and the rest categorized as current "smokers" [26].

Statistical analysis was performed using SPSS20 (SPSS Inc., Chicago, IL, USA). Primary outcome was analysed by Kaplan-Meyer survival rates and Breslow Test. Influence on implant loss was tested with a Cox-regression analysis. Differences between groups regarding secondary variables were measured using a *t* test. Two-sided *p* values were assessed and statistical significance was declared for *p* values ≤0.05.

Results

A cohort of 29 subjects with history of periodontitis and implant-supported prostheses, following APT, was eligible to be included in the test group, according to the defined criteria. Their average age (15 females and 14 males) at the beginning of periodontal therapy (T0) was 49.7 ± 11.2 years (range 23–75 years) and 56.0 ± 10.8 years (range 25–76 years) at implant insertion (T1).

For the control group, 29 patients without periodontitis (15 females and 14 males, mean age of 55.7 ± 10.4 years, range 28–71 years) were consecutively recruited and pair-matched with the test group. The percentage of active smokers, former smokers and non-smokers were 86% ($n = 25$), 10% ($n = 3$) and 4% ($n = 1$) in the test and in the control group 93% ($n = 27$), 7% ($n = 2$) and 0%, respectively. Patients' demographic details including teeth/implants lost are shown in Tables 1 and 2.

In the test group, all patients were initially diagnosed with generalized chronic periodontitis ($n = 29$; 24% light ($n = 7$), 59% moderate ($n = 17$) and 17% severe ($n = 5$)). During the observation period, no patient in the control group was diagnosed for periodontitis; however, some showed signs of repeated local gingivitis at different teeth.

The total number of teeth before implant insertion was 649, with an average of 22.4 ± 5.0 teeth/patient in the test group (control group 624; 21.5 ± 5.1 teeth/patient). Three patients in the control group had dental implants before T1 (test: 0). Patients' distribution according to the number of fixed versus removable prosthesis was similar in test and control group (Table 1), whereas one patient had both types simultaneously in the control group. The locations of all 69 implants in test (control 76) group are shown in Fig. S1 (Supplement).

According to the periodontal status of teeth during the observation time, 90% (27 of 29) of the test group had residual pockets of ≥4 mm at T1, and the number ranged from 2 to 15 pockets per subject (control group 2 (7%) with 2–9 pockets per subject). In both groups during maintenance, no pocket elimination surgery, osseous resection, augmentation of intrabony defects, or other regenerative periodontal therapies were undertaken. Splinting of mobile teeth was performed in two cases in the lower incisor region (test one patient; control one patient). In the test group, three patients in the APT and one patient during SPT (control 0 patient), presenting with persistent inflammation, received mechanical periodontal therapy in addition to adjunctive metronidazole/amoxicillin antibiotics [27].

According to the implant-associated complication during the observation period of T1 to T2, four patients in the test group (control six patients) were treated via non-surgical

Table 1 Demographic data

Number of subjects	Test group 29	Control group 29
Males/females (%)	14/15 (48.3%/51.7%)	14/15 (48.3%/51.7%)
Mean age ± SD [range] (years) at T1	56.0 ± 10.8 [25–76]	55.7 ± 10.4 [28–71]
Mean age ± SD [range] (years) at T2	66.8 ± 8.6 [42–81]	63.2 ± 10.0 [39–76]
Mean follow-up ± SD [range] (years) (T1–T2)	11 ± 5.6 [5–23]	7.6 ± 3.6 [5–19]
Number of patients with fixed prosthesis	27	26
Number of patients with removable prosthesis	2	2
Number of patients with fixed and removable prosthesis	0	1
Non-smokers at T1 (%)	25 (86.2%)	27 (93.1%)
Former smokers at T1 (%)	3 (10.3%)	2 (6.9%)
Smokers at T1 (%)	1 (3.4%)	0
Diabetes disease at T1 to T2: no/yes (%)	27/2 (93.1%/6.9%)	29/0
Coronary heart disease at T1 to T2: no/yes (%)	17/12 (58.6%/41.4%)	27/2 (93.1%/6.9%)

T1 after active periodontal therapy and at implant insertion, *T2* temporally end of supportive periodontal therapy, respectively supportive postimplant therapy

therapy (plastic curettes and rubber cup polishing). No patient received surgical therapy in both groups.

Tooth loss during T1–T2

During APT, 91 out of 649 (14.02%) teeth were extracted in the test group. In addition, 39 of 558 (6.99%) teeth present at T1 were lost during a mean observation period of 11.0 ± 5.6 years (range 5–23) of SPT, yielding 519 teeth present at the final SPT-visit (T2). Conclusively, patients in the test group lost 130 out of 649 (20.0%) teeth until T2.

Patients in the control groups lost 17 out of 624 (2.7%) teeth before implant insertion. In the observation time of 7.6 ± 3.6 years, additional 23 teeth out of 607 (3.8%) got lost. Hence, in total at T2, 40 (6.4%) teeth were extracted.

Survival of implants during T1–T2

In the test group, 97.1% of dental implants survived over 5 years and 92.5% over 10 years (control: 5 years survival rate 97.4%; 10 years survival rate 91.4%). In total, 69 implants were examined in the test group between T1 and T2, with a mean of 2.4 ± 1.3 (range 1–5) per patient. Eight implants (11.6%) in four patients (13.8%) were lost during the period of investigation, whereas one patient lost one implant, two patients lost two implants and one patient lost all three implants under investigation.

In the control group, 76 implants (2.6 ± 2.2 [range 1–12] per patient) were evaluated. Five patients (17.2%) lost seven implants (9.2%). Three patients lost one implant and two patients lost two implants. In total in both groups, 15 implants (10.3%) were lost in 9 patients (15.5%), whereas 49 patients (84.5%) lost no implant during the observation time. There was no significant difference in implant survival between groups (Fig. 1, $p = 0.562$).

Pocket probing depths and marginal bone loss of implants

Mean PPDs at T1 were 3.4 ± 1.0 mm in the test and 1.0 ± 1.2 mm in the control group. In both groups, mean PPD increased significantly at T2 (test 4.2 ± 1.6 mm; control 2.9 ± 0.8 mm) ($p < 0.05$). At T1 as well as at T2, the PPDs differed significantly between groups ($p < 0.05$).

Table 2 Presence of implants and teeth

	Test group		Control group	
	T1	T2	T1	T2
Mean number of present teeth ± SD	19.2 ± 5.8	17.9 ± 6.2	20.9 ± 5.5	20.1 ± 5.8
Total number of present teeth	558	519	607	584
Number of screened implants	69	61	76	69
Number of lost teeth ± SD between T1 and T2	39		23	
Number of lost implants ± SD between T1 and T2	8		7	

T1 after active periodontal therapy, *T2* temporally end of supportive periodontal therapy, respectively supportive postimplant therapy

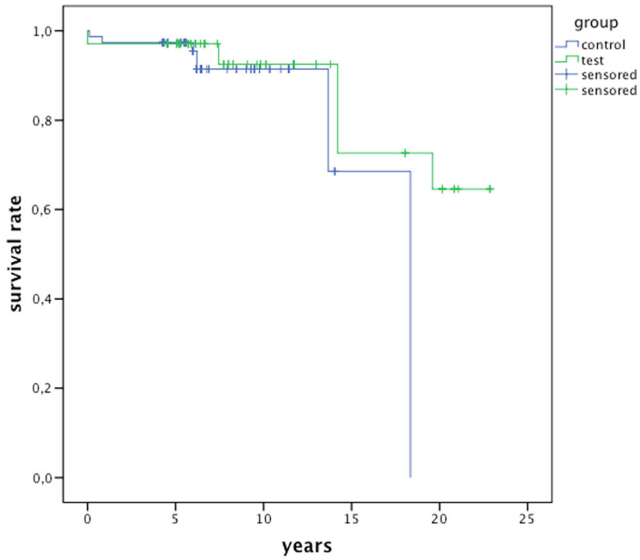

Fig. 1 Survival rates of implants according to groups

Radiological measured MBL was 6.8 ± 13.7% in the test group and 1.4 ± 9.2% in the control group at T1. At T2, values rose to 15.7 ± 17.8 and 4.8 ± 13.2%. Differences between groups and time points for MBL were statistically significant (Fig. 2, $p < 0.05$).

Prognostic factors for loss of implants

After the stepwise selection process, the following variables at T1 were evaluated in a final risk model: group, gender, age and MBL. MBL in steps of 10% at T1 (OR 1.81; 95% CI 1.34–2.45), number of PPDs ≥4 mm on all teeth (OR 1.90; 95% CI 1.33–2.72) and age at T1 (OR 1.16; 95% CI 1.0–1.34) were significantly linked to implant loss (see Table 3). The diagnosis of periodontitis (test group) did no significant risk for implant loss (OR 0.001; 95% CI 0.00–0.39).

Mean PPD, pathological PPDs around implants at T1, number of teeth and documented diabetes or coronary heart disease did not pose a risk on implants' survival. Smoking was not evaluated, as only one patient in the test group smoked during the observation time.

Discussion

The present clinical retrospective cohort study investigated the long-term survival of dental implants in periodontally compromised patients, following APT as compared to periodontally healthy patients. Within the limitations of the present study, principal findings demonstrated that implants in periodontally compromised patients had a survival rate of 92.5% over 10 years, if a thorough APT was performed, followed by regular SPT and SIT. Nevertheless, during maintenance, MBL and PPD differed significantly in patients with and without history of periodontitis.

Loss of implants

The decision whether to extract a tooth and to replace it by a dental implant should be made cautiously, as "extraction is a definitive and irreversible treatment" [22, 28]. According to Ramfjord (1977) and Rosling et al. (2001), periodontal stability can be maintained over long periods in well-controlled patients, despite the presence of residual pockets and restricted oral hygiene. In the present study, six patients in the test group

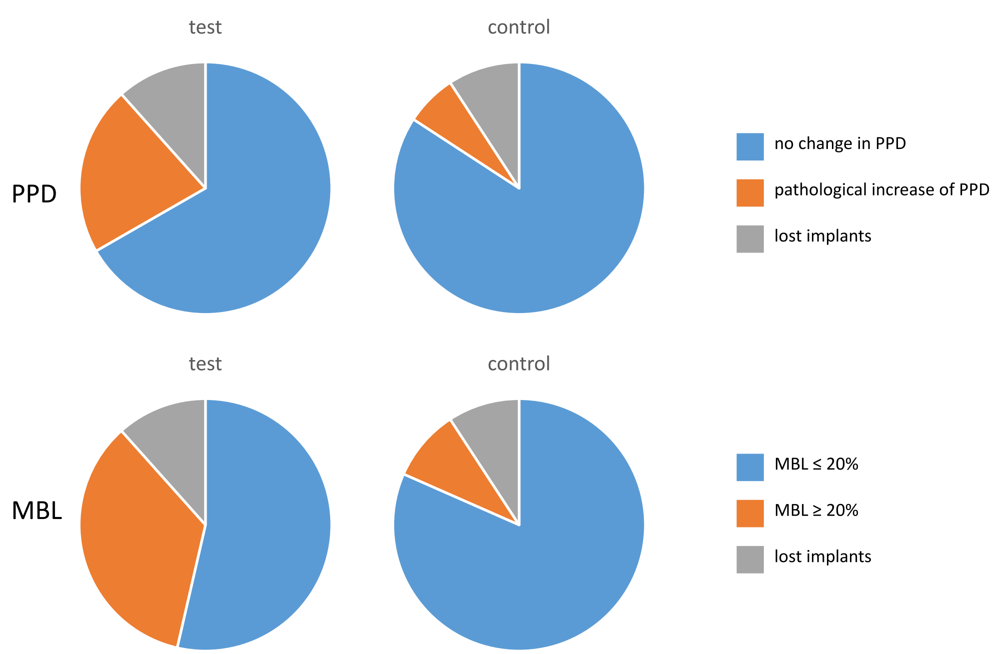

Fig. 2 Number of implants with pathological values after observation time T1–T2. Increase of pathological values (increase of PPDs with ≥3 mm at T1 more than 2 mm or >5 mm at T2) and MBL with loss of >20% up to T2 separated for survived and lost implants

Table 3 Results of the cox-regression analysis after stepwise selection of variables

Variables at T1	OR	95% CI	*p* value
History of periodontitis	0.001	0.00; 0.39	<0.001
Gender	0.62	0.16; 2.41	0.486
Age	1.16	1.0; 1.34	0.040
MBL	1.811	1.34; 2.45	<0.001
Number of PPDs ≥4 mm	1.90	1.33; 2.72	<0.001

Independent variable is implant loss during observation time

lost more than half of all 130 extracted teeth, whereas nearly five times less tooth loss was documented in the control group (five patients lost more than 20 teeth of all 40 extracted teeth). In a previous investigation on 68 patients over an observation time of 16 years, each patient lost on average 0.15 teeth/year after primarily conservative periodontal therapy during the individualized SPT [22]. A recent published systematic review confirmed these findings and emphasized the underestimated risk for tooth loss ranging between 3.6 and 13.4% during long-term SPT of more than 15 years [28]. The authors further concluded that implant survival rates do not exceed those of compromised, but adequately treated, teeth. Correspondingly, the present study, including patients with moderate to severe chronic periodontitis (74%), showed a tooth loss of 6.9%, confirming that the overall tooth loss for an observation period of 10 years is not affected, when the teeth are properly treated and periodontally maintained [22, 29].

During the last 30 years, reported implant loss rates varied considerably between studies on patients with history of periodontitis [28], making the long-term survival of implants in these patients ambiguous, as well as of great interest for the clinical decision-making. In comparison to 0.12 teeth lost/patient/year, 0.025 implants/patients/year in patients without periodontitis and correspondingly 0.032 implants/patients/year in patients with treated periodontitis were lost in the present study. This corresponds to a survival rate of 92.5 and 91.4% ($p = 0.562$), for test and control groups, respectively, comparable to data form an earlier systematic review [28] and in contrast to results of earlier studies, demonstrating significant lower implants' survival rates for patients with history of periodontitis [30–32]. These differences in the results appear to stem from the fact that it is not the history of periodontitis per se, which worsens the prognosis for dental implants, but that rather the patients' genetic disorders (e.g. aggressive periodontitis or metabolic syndromes), as well as patients' habits (e.g. smoking), could pose a risk for long-term implant survival [33]. According to a recent consensus report, the combined cellular responses, possibly induced through e.g. smoking or diabetes, could culminate in an imbalance osteoblasts and osteoclasts functions [33]. De Boever et al. [18] showed that smoking had a significant influence on implants' survival, especially in patients with generalized aggressive periodontitis, with a resultant reduction in the overall survival in current smokers by 17%. It appears that the contribution of each risk factor, the presence or absence of synergism between the factors [28], and the presence of uncontrolled confounding factors [15, 33] remain largely unknown. Due to the very low number in total as well as an unequal distribution of smoking (1 vs. 0) and diabetes (2 vs. 0) between subjects, the current investigation failed to show significant influences of general health or smoking on implant survival.

Patients' age at T1 (test 56 ± 11 years; control 56 ± 10 years; OR 1.161) was significantly linked to implant loss. Although ageing is a cumulative intractably complex process with multiple forms of damage observed in different tissues [34], age alone appears not to be a limiting factor for a successful dental implant therapy [35]. Nevertheless, given the predicted demographic change with more elderly people and therefore possibly smoking [36, 37] and/or systemic morbidities, mainly diabetes, [38, 39], both the incidence of periodontitis and peri-implantitis can be expected to further increase in the elderly. The current study, however, demonstrated no difference in implant survival rate, between periodontitis versus non-periodontitis patients, for subjects with a mean age of nearly 56 years.

Although different mRNA signatures were demonstrated between periodontitis and peri-implantitis [40], studies have identified major similarities in their pathogenesis [41, 42], with the same pathogenic bacteria implicated in the aetiology and progression of both diseases [43–45]. Therefore, an effective periodontal treatment prior to the placement of osseointegrated dental implants seems to be of major importance.

Generally, implant complications are complex and multifactorial and could be categorized into early and late events. The early ones, similar to the ones noted in the control group after 1 year, are often due to failure in the operative procedure, whereas the later ones are rather due to biological and technical complication e.g. peri-implantitis [46]. In the current study, implants' loss in test group was recognized after ≥5 years. A possible explanation could be that with an established periodontal diagnosis and the enrolment of patients and their compliance in APT and regular SPT programs [47], the risk for further periodontal destruction [48] is reduced. According to the recent systematic review by Zangrando et al. [49], patients in the test group seem to have been aware of their periodontal status and possible complications and were consequently more careful with their oral condition, following implant insertion. This might explain the contrary significant trend for the risk of losing implants (OR 0.001; 95% CI 0.00–0.39) in the test group and underlines once more the need for a supportive periodontal as well as implant treatment phase. However, the same systematic review further underlined that in addition to smoking and non-attendance to the periodontal maintenance programs, residual pockets were a negative factor for the long-term implant outcomes [49].

Residual PPD and MBL at implants

Although all patients in the test group were efficaciously treated in terms of tooth survival, they displayed residual pockets at the end of APT (T1). At T1, mean PPD differed significantly between the groups with a difference of almost 2 mm. In both groups, a significant increase in mean PPD was further measurable (around 1 mm in the test and 2 mm in the control group). These residual periodontal niches may serve as bacterial reservoir for further destruction [50]. Ninety percent of the patients in the present study were therefore more susceptible for periodontal complication [51, 52] and were thus less successfully treated than others.

Radiological measured MBL at T1 was 6.8 ± 13.7% in the test and 1.4 ± 9.2% in the control group. At T2, values rose to 15.7 ± 17.8 and 4.8 ± 13.2%, respectively. Differences between groups and time points were statistically significant. A similar finding was observed for MBL in both groups. In the test group, an increase of nearly 10% bone loss was measured, whereas only 3% was measured in the control group. A 34.8% of all the survived implants in the test group and 9.2% in the control group demonstrated a bone loss of 20% or more. Irrespective of the implant system used or of the classification of peri-implantitis [50], 20% MBL change in the test group could be certainly interpreted as a progressive destruction, comparable to earlier 10 years cohort studies [3, 53].

Current and earlier results [3, 49] support the concept that in periodontitis susceptible patients with residual pockets at the beginning of SPT, the risk for peri-implantitis induced bone loss and subsequent implants' loss is increased. In the current investigation, only one patient in the test group, presenting with a persistent inflammation in the molar region, received in addition to repetitive mechanical periodontal therapy adjunctive metronidazole/amoxicillin antibiotics [27]. However, according to implant-associated complication all 10 patients (test/control 4/6 patients) were adequately treated with a non-surgical therapy, not necessitating a surgical intervention. In total, 15.5% of all 58 patients lost 10.3% of all 145 implants (test/control 8 implants in 4 patients/7 implants in 5 patients). Therefore, it seems necessary to plan and declare to each patient a standardized protocol for regular SIT [54], with measurement of PPDs and radiological control of the MBL around implants, independent of the presence of a history of periodontitis [47, 55], to ensure long-term treatment results' stability.

Nevertheless, current outcomes indicate that natural teeth yielded long-term results, with respect to survival rate and MBL changes, comparable to dental implants. As a consequence, Rasperini et al. [56] demand that the decision for tooth extraction attributable to periodontal reasons in favour of dental implants should be carefully considered in partially edentulous patients.

Limitation

Retrospective data analyses have limited level of evidence, with a risk of selection, performance, or reporting bias. However, it is critical to develop well-designed, long-term prospective studies to provide further substantive evidence on the association of periodontal disease, especially severe forms, and implant loss [13]. It is furthermore not possible to prove the influence of maintenance on survival of the investigated implants in the current setting, since no control groups without a maintenance program were included. Additionally, only compliant patients with regularly visits in both departments were consecutively recruited. The external validity of these findings is thus limited, since the procedure and effectiveness of maintenance in general dental practice might be different to the ones in a university setting [22, 51, 52]. However, some of these limitations were tried to be overcome, by consecutively choosing patients and thus limiting selection bias. Groups (periodontitis versus non-periodontitis) were balanced according to size, used diagnostics, and performed periodontal, prosthodontic and implant treatment [6, 22]. However, although all 29 patients of the test group had periodontitis and bone loss, differences remain in the distribution of severely affected teeth and implants as well as the severity of the periodontal disease [22]. Bleeding on probing or occlusal/functional exposure was not amenable for evaluation, due to incomplete data, which surely affected the clinician's subjective decision [28]. However, the present study did not investigate in detail the different kinds of prosthetic rehabilitation, whereas there is evidence in recent literature that prosthetic restoration has a significant effect on long-term implant prognosis [57]. Another limitation is the conducting of bone level measurements on radiographs, being generally responsible for large standard deviations [58, 59]. The technique and type of all radiographs investigated were not standardized. However to increase reproducibility of measurements, the same investigator assessed the required parameters on all radiographs. The time points of radiographic investigation are hereby very important. Under clinical condition, it is possible to take radiographs at the time of implant placement or loading, ideally at both time points to verify any significant bone loss [60]. In the current study, radiographic examinations were performed at implant placement (T1), which may have a biasing effect on the results, since no clear distinction could therefore be made between immediate postoperative bone loss following surgical manipulation/complications or as a result of biologic complication e.g. peri-implantitis.

The last point to be critically considered in analysing the current results is the on-going development in the implant systems [55, 61, 62] and the missing information about bone augmentation prior to implantation [63], which might influence implant survival independent of a history of periodontal disease. Otherwise, it should be noted, that since the beginning of the observation phase in the 1980s, developments in implant systems, implant designs, implant connections, and implant surfaces have not been considered a major factor regarding the longevity of implants inserted in patients susceptible to periodontitis [64].

Conclusions

Within the limits of the present longitudinal study, we may conclude that conservative periodontal therapy, including a SPT phase, results in a good prognosis of teeth and implants for at least 10 years of follow-up. Due to compliance to a strict regime during the SPT phases, no differences in terms of implant survival rates between periodontitis susceptible patients and patients without periodontitis were observed. However, patients with the history of periodontitis showed, independent of the enrolment in a regular SPT, higher MBL and PPD, which could pose a significant prognostic factor for implant survival.

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Compliance with ethical standards

Conflict of interest Author Christian Graetz declares that he has no conflict of interest. Author Karim Fawzy El-Sayed declares that he has no conflict of interest. Author Antje Geiken declares that she has no conflict of interest. Author Anna Plaumann declares that she has no conflict of interest. Author Sonja Sälzer declares that she has no conflict of interest. Author Eleonore Behrens declares that she has no conflict of interest. Author Jörg Wiltfang declares that he has no conflict of interest. Author Christof E. Dörfer declares that he has no conflict of interest.

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