Long-term analysis of osseointegrated implants in non-smoker patients with a previous history of periodontitis


Abstract

Aim: To evaluate long-term clinical and radiographic parameters of osseointegrated implants in non-smoker patients with a previous history of chronic periodontitis.

Materials and Methods: Fifty-four screw-type implants with a moderately roughened surface and internal hexagonal implant–abutment connection were placed according to a two-phase protocol and 40 reference teeth were analysed at baseline, and after 5 and 10 years. Pocket probing depth (PPD), clinical attachment level (CAL) and bleeding on probing were analysed 6x/tooth in all teeth, implants and reference teeth. Radiographic peri-implant bone level was measured on the mesial and distal surfaces. The prevalence of peri-implantitis and the survival rate of the implants were assessed at the patient and implant levels. Data were analysed using descriptive statistics, Mann–Whitney U-test, and Wald Z-test, at α = 5%.

Results: In implants, the CAL at 5 years was 0.3 mm higher, and at 10 years 1.2 mm higher in comparison to baseline. The corresponding data for the reference teeth were 0 mm and 0.5 mm respectively. Multilevel testing showed statistical difference for PPD between implants and teeth over time. After 10 years, the mean mesial bone loss was 0.63 ± 0.26 mm, and the mean distal bone loss was 0.56 ± 0.25. The survival rates were 100% and 92.3% for the implants in the mandible and the implants in the maxilla respectively.

Conclusions: Screw-type implants with internal hexagon placed in patients with a previous history of periodontitis attending a regular maintenance programme demonstrated stable clinical and radiographic results after 5 and 10 years.

Conflict of interest and source of funding statement

The authors declare that they have no conflicts of interest. No external funding, apart from the support of the authors’ institution, was available for this study. The authors declare that there are no conflicts of interest in this study.

Since the early 1980s, the use of titanium dental implants has become a predictable treatment for oral rehabilitation of completely or partially edentulous patients (Branemark et al. 1977, Adell et al. 1981). Since the early years, the clinical indications for implant therapy have increased considerably. To date, dentists can choose among a variety of systems and surgical possibilities for implant treatment. The high, long-term predictability that has been shown for implant therapy in partially edentulous patients is an important factor in this development (Hermann et al. 1997, Hultin et al. 2000, Rutar et al. 2001, Rasmusson et al. 2005, Roos-Jansaker et al. 2006, Esposito et al. 2007, Grutter &
Belser 2009). Systematic reviews have reported survival rates of implants of more than 95% after an observation period of at least 5 years (Pjetursson et al. 2004, den Hartog et al. 2008, Jemt 2008, Aglietta et al. 2009). In addition, one systematic review reported survival rates of 95.5% addressing immediate, early and conventional implant approaches, when single-implant restorations in the aesthetic zone with adjacent natural teeth were evaluated (den Hartog et al. 2008).

Retrospective evaluations of screw-type implants with internal hexagon demonstrated similar survival rates higher than 90% as with other systems, after a period of 5 years (Gomez-Roman et al. 2001, Krennmair et al. 2002, Krennmair & Waldenberger 2004, Ricci et al. 2004, Strietzel et al. 2004). The implant system (Friialit-2; Dentsply, Mannheim, Germany) represents the evolution of the Tuebingen tapered ceramic implant (Albrektsson & Wennerberg 2004a). The implant system has a sandblasted and etched surface (Albrektsson & Wennerberg 2004a). Its tapered macrodesign offers the possibility of placing the implants in slight maxillary or mandibular concavities and near adjacent teeth with converging roots. Furthermore, the wide-diameter implants were conceived to enable the elaboration of emergence profiles that were closer to the natural dentition. The implant system proved to be successful in all areas of indication in partially edentulous patients after an observation period of a maximum of 7 years (Krennmair et al. 2002). However, to date, no study has reported retrospective or prospective data of this implant system placed in patients with a history of periodontitis.

In recent years, authors have evaluated the long-term success of various implant systems in patients with periodontitis, showing different results (Mengel et al. 2001, Hardt et al. 2002, Baelum & Ellegaard 2004, Karoussis et al. 2004, 2007, Malo et al. 2007, Arisan et al. 2010, Garcia-Bellosta et al. 2010, Gianserra et al. 2010, Simonis et al. 2010, Simonis et al. 2007, Carcuac & Jansson 2010, Simonis et al. 2010, Koldsland et al. 2011, Swierkot et al. 2012). Moreover, the few studies reporting results of implant therapy in patients with periodontitis after 10 and more years are not conclusive. A 10-year retrospective analysis of radiographic bone level changes in implants supporting single-unit crowns in periodontitis versus periodontally healthy patients showed that implants in periodontitis patients yielded lower survival rates and higher mean marginal bone loss rates compared with those of implants placed in periodontally healthy patients. The results were independent of the implant system used and the healing modality applied (Matarasso et al. 2010). A systematic review of the risk of implant failure and marginal bone loss in subjects with a history of periodontitis reported that periodontitis subjects were at significantly higher risk for implant failure and greater marginal bone loss compared to periodontally healthy subjects (Safi et al. 2010). These clinical findings are aggravated in smokers (Aglietta et al. 2011, Levin et al. 2011). After 10 years, implants placed in smokers with a history of treated periodontitis and enrolled in a supportive therapy programme yielded lower survival rates and higher marginal bone loss rates compared with those of implants placed in periodontally healthy smokers (Aglietta et al. 2011). Despite these reports, results of a further systematic review on implant treatment in periodontitis-susceptible patients demonstrated that the survival rates of implants were high in individuals with a history of periodontitis (Schou 2008). Nevertheless, a higher incidence of peri-implantitis was also found in these patients.

The majority of studies and systematic reviews addressing the long-term effects of implant therapy in association with periodontitis have been performed in patients with chronic periodontitis. Studies in patients with a history of aggressive periodontitis are scarce (Mengel et al. 2007, De Boever et al. 2009). A 10-year prospective analysis of implants in subjects treated for generalized aggressive periodontitis demonstrated that bone and attachment loss around implants in these patients were higher than in periodontally healthy subjects, or patients with chronic periodontitis (Mengel et al. 2007, De Boever et al. 2009).

The aim of this prospective study was to evaluate the long-term results at 5 and 10 years of two-stage screw-type implants with internal hexagon placed in patients with a previous history of periodontitis.

Materials and Methods

Patient selection

Patients with chronic periodontitis were included in this prospective study at the Department of Periodontology, Dental School, Justus-Liebig-University of Giessen, Germany. The diagnosis of chronic periodontitis was based on the recent international classification of periodontal diseases and conditions (Flemmig 1999, Tonetti et al., 2005). Twenty patients (nine males and eleven females) participated in the study. The patients were included according to the following criteria: Age ≥ 18 years, absence of relevant systemic conditions, 4–6 months of healing after tooth extraction and presence of sufficient residual alveolar bone volume for achieving primary implant stability. All patients were partially edentulous, with missing single or multiple teeth. The reported association between periodontitis and implant loss/peri-implantitis may be confounded by smoking (a risk for both conditions). As smokers are at higher risk for developing peri-implantitis, to avoid bias, smokers were not included in the study (Roos-Jansaker et al. 2006). The study was approved by the ethics committee of the University of Giessen. All patients gave their written informed consent. The study was conducted in accordance with the ethical guidelines of the Helsinki Declaration and with the
guidelines of good clinical practice (GCP).

Periodontal treatment

All patients underwent systematic periodontal therapy. The periodontal treatment consisted of a hygienic phase, achieving full-mouth plaque and bleeding scores ≤30% before implant placement. After supragingival professional tooth cleaning, subgingival debridement in the form of scaling and root planing was performed in all teeth with probing pocket depth ≥4 mm and bleeding on probing (BOP). The therapy was performed with manual and mechanical instruments by an experienced dental hygienist. If necessary, reconstructive or regenerative periodontal surgeries were performed by two experienced specialists for Periodontology (J.G., J.M.). Thereafter, all patients actively took part in a regular supportive periodontal treatment programme. During the first year, they were evaluated at intervals of 3–4 months; subsequently, patients were recalled at intervals of 6 months.

Implant placement

The patients were consecutively provided with implants (Frialit-2; Dentsply, Mannheim, Germany). This type of implant has a rough surface with a grit-blasted and thermal etched Friadent® plus microstructure, with the exception of the most cervical portion, where a smooth collar was present (Albrektsson & Wennberg 2004b). The implants were placed following the classic two-stage protocol by two experienced specialists in periodontology and implantology (J.M., J.G.). Implants were usually inserted using a pre-fabricated stent with the implant guides and positioned with the coronal border of the rough surface at the level of the alveolar bone crest and left to heal under the mucoperiosteal flap. After 4–6 months of osseointegration, the prosthetic restorations were built on the implants by the same two specialists who performed the surgeries. The abutments used were matching in all cases without exception. The prosthetic treatment of choice was cemented single crowns. This time point was considered to be the baseline for the further analyses. All patients received oral hygiene instructions to maintain appropriate oral hygiene around the implants and remaining teeth. In total, 54 implants were placed and analysed at baseline, and at the 5- and 10-year follow-up examinations.

Clinical evaluation

Clinical and radiographic evaluations were performed at the stage of loading (baseline) and at least every year. Specifically after 5 and 10 years, a complete documentation of periodontal and peri-implant conditions was recorded, using the following parameters: pocket probing depth (PPD), clinical attachment level (CAL) and BOP (6x/tooth), using a PCP UNC 15 periodontal probe. Oral hygiene indices included the O’Leary simplified plaque index and the papillary bleeding index (4x/tooth) (O’Leary et al. 1972, Saxer & Muhlemann 1975). The clinical parameters were assessed for all teeth, and specifically for the reference teeth. These teeth were matched to the implants according to their position, as there were the teeth located on the contra-lateral side of the implants. These teeth were analysed as a reference to the implants, since data from long-term (10 years) controlled studies comparing teeth and implants in well-maintained patients demonstrated that changes in soft tissues occurred in a similar manner around implants and around teeth (Klinge et al. 2006). The clinical parameters PPD, CAL and BOP of the implants were measured analogously to that of the natural teeth. In implants, CAL was the distance from the crown margin to the deepest point reached by the pocket probing depth. These measurements were performed without local anaesthesia, thus, they were not bone sounding measurements.

Radiographic examination

Patients were screened by panoramic X-rays taken after implant surgery, and at every 24 months thereafter. At the time of crown insertion (baseline), and at the 5- and 10-year follow-up examinations, periapical radiographs were obtained using the parallel long-cone technique. These were used to calculate the marginal bone level changes of the implants. The previously calibrated radiographic examinations were performed separately by two different investigators (G.G. and J.G.). The location of the marginal bone level in relation to the implant shoulder was assessed at the mesial and the distal sites of the implants using a magnifying loupe 2X (120 mm diameter; GFS, Warstein, Germany) and an x-ray viewer Planilux 61 × 61 cm (Planilux® GmbH, Warstein, Germany) (Gomez-Roman et al. 1997). Two distances were measured: (a) the distance from the implant shoulder to the deepest contact of the marginal bone with the implant surface (bone to implant level) and (b) the distance from the implant shoulder to the highest point of the crestal marginal bone in the inter-dental space (crestal peri-implant level).

Definition and prevalence of peri-implantitis

For assessing peri-implantitis, the definition used in this study was modified from previously reported definitions (Lindhe et al., 2008, Koldsland et al. 2011, Lang et al., 2011). The definition used was as follows: loss of radiographic bone (at the mesial, or the distal, or both peri-implant sites) after 5 or 10 years compared to baseline, combined with BOP/suppuration (at least at one peri-implant site). The prevalence of peri-implantitis after 5 and 10 years was analysed on the implant and subject levels. Thus, the percentages of implants and subjects presenting with loss of radiographic bone combined with BOP/suppuration were calculated.

Data analysis

The statistical analysis included a descriptive analysis of the data, consisting of mean values and standard deviations (SD). Three time points were evaluated: baseline was the time when the implants were loaded with the supra-structure, and from that point, the evaluations after 5 years, and after 10 years followed. The variables taken into consideration for the statistical analysis were as follows: pocket probing depth (PPD), clinical attachment level (CAL) and BOP (6x/sites) of the implants, and of the reference teeth. In addition, to demon-
strate the periodontal status of the patients, the clinical parameters PPD and CAL were assessed in all teeth, and divided into three measurement categories: (a) 1–3 mm, (b) 4–5 mm and (c) >5 mm.

The primary outcome variable was the change in CAL at implants and reference teeth between baseline and 5 years, and baseline and 10 years. The null hypothesis was: there are no changes in CAL between these time points. As the primary outcome variable is the change in CAL, the implant (and not the patient) was taken as the statistical unit, despite the fact that multiple implants were present per patient. To correct for within-patient dependency, multilevel modelling was used to determine the effect over time on the clinical parameters CAL, PPD and BOP (Wald Z test). Since follow-up was conducted at irregularly time intervals, time was included in the model. The differences in the clinical parameters between the two time points, baseline and 5 years and baseline and 10 years, were evaluated using the Mann–Whitney U-test. In addition, the analysis of the difference in CAL after 10 years between implants and reference teeth was performed using the unpaired t-test. A p-value of <0.05 was considered to indicate a statistically significant difference.

The cumulative survival rate (CSR) was calculated using the Kaplan–Meier analysis which is a good indicator of the cumulative survival rate. All statistical analyses were performed using IBM SPSS Statistics 20 software (IBM Corp. 2011, NY, USA).

Results

Clinical measurements

The population consisted of nine males and eleven females. The mean age of the patients at baseline was 48.7 ± 8.9 years. 43.9% of the implants were placed in the posterior mandible, 33.6% in the posterior maxilla, 14.6% in the anterior maxilla and 7.8% in the anterior mandible. The distribution of the diameter of the implants was 51.8% (4.5 mm), 33.6% (3.8 mm) and 14.5% (5.5 mm). The distribution of the length of the implants was 54.5% (13 mm), 40.2% (15 mm), 2.7% (11 mm) and 2.6% (10 mm).

Table 1 shows the mean values and SD of the number of teeth per subject, and the clinical parameters PPD, CAL and BOP of all teeth at the three examination times: (a) baseline, (b) examination after 5 years and (c) examination after 10 years. The mean number of teeth decreased from 17.1 to 15 after 10 years. Mean PPD and CAL of all teeth demonstrated a slight increase after 5 years (0.1 mm and 0.2 mm respectively). After 10 years, both mean PPD and CAL increased in comparison to the baseline values (0.3 mm and 0.4 mm respectively). Similarly, the mean percentages of BOP slightly increased after 5 years (1.7%), and after 10 years (3.1%), in comparison with the baseline mean value.

The clinical parameters PPD and CAL of all teeth were also subdivided into three measurement categories to analyse the periodontal status of the patients: 1–3 mm, 4–5 mm and >5 mm. The percentage of sites with PPD 1–3 mm decreased, and the percentage of sites with PPD 4–5 mm and those >5 mm increased after 10 years. Similar changes were observed for the parameter CAL.

Table 2 shows the mean values ± SD of the clinical parameters of the implants at baseline, at the 5-year and at the 10-year examinations. In comparison to the baseline PPD and CAL mean values, both parameters showed higher mean values at the 5-year examination (0.3 mm, p < 0.05, Mann–Whitney U-test). After 10 years, the mean PPD and the mean CAL were 0.7 mm and 1.2 mm higher, respectively, in comparison with the baseline values (p < 0.05, Mann–Whitney U-test). The mean percentage of BOP was 5% lower at 5 years compared to baseline. After 10 years, the mean percentage of BOP was 6% higher in comparison with the baseline value. With regard to BOP, there were no differences between the two time points.

Table 3 shows the mean values ± SD of the clinical parameters of the reference teeth at the three time points. Whereas the mean PPD and CAL values at the 5 years examina
tion were similar to that of baseline values \((p > 0.05, \text{Mann–Whitney } U\text{-test})\), after 10 years, the values of both parameters were 0.5 mm higher than those at baseline \((p < 0.05, \text{Mann–Whitney } U\text{-test})\). Similar to the implants, the mean percentage of BOP was 5% lower at 5 years and 2% higher at 10 years compared to the percentage at baseline. However, no differences were calculated for this parameter between the two time points.

In this study, we further evaluated the differences in the CAL measurements at baseline and at 5 years, and at baseline and at 10 years. The results are shown in box plots. The horizontal line inside the box marks the median value. The box is where the main data reside, covering 50% of the data around the median. The lower line of the box marks the 1st quartile, the upper line the 3rd quartile. The whiskers, the vertical lines extending from the box, mark the smallest and highest value, except the outliers. If the distance of a value from the box is more than 1.5 times the length of the box it is identified as an outlier, represented by an “o” or an “*”. Figure 1 demonstrates the CAL change in the implants. A higher change in the CAL was determined from baseline to 10 years, compared to the change from baseline to 5 years \((p < 0.05, \text{t-test})\). Conversely, in the reference teeth no differences were determined in the change in the CAL from baseline to 10 years in comparison with the change in the CAL from baseline to 5 years (Fig. 2).

The results from the multilevel analysis regarding the clinical parameters CAL, PPD and BOP over time are shown in Table 4. The parameter PPD showed significant differences between implants and reference teeth over time. No significant differences were observed over time between implants and reference teeth in CAL and BOP.

### Radiographic bone levels of implants

The mean bone to implant measurements on the mesial side were: 3.55 ± 1.69 mm at baseline, 3.71 ± 1.59 mm at 5 years and 4.18 ± 1.95 mm at 10 years. On the distal side, the corresponding values were: 3.66 ± 1.63 mm at baseline, 3.89 ± 1.97 mm at 5 years and 4.22 ± 2.15 mm at 10 years. The mean crestal peri-implant bone measurements on the mesial side were: 2.45 ± 1.36 mm at baseline, 2.46 ± 1.37 mm at 5 years and 2.63 ± 1.30 mm at 10 years. On the distal side, the corresponding values were: 2.51 ± 1.15 mm at baseline, 2.52 ± 1.44 mm at 5 years and 2.89 ± 1.40 mm at 10 years. Thus, the mean loss of bone to implant level after 5 years was 0.16 ± 0.10 mm on the mesial side and 0.23 ± 0.34 mm on the distal side. The mean loss of bone to implant level after 10 years was 0.63 ± 0.26 mm on the mesial side and 0.56 ± 0.25 mm on the distal side.

#### Table 3. Mean values ± standard deviation (SD) of the clinical parameters in the reference teeth at baseline, at the 5-year and at the 10-year follow-up examinations \((n = 40)\)

<table>
<thead>
<tr>
<th>Time</th>
<th>Baseline</th>
<th>5 years</th>
<th>10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPD ((\text{mm}))</td>
<td>2.1 ± 0.6</td>
<td>2.2 ± 0.7</td>
<td>2.6 ± 0.8♀</td>
</tr>
<tr>
<td>CAL ((\text{mm}))</td>
<td>2.4 ± 0.8</td>
<td>2.4 ± 0.8</td>
<td>2.9 ± 1.2♀</td>
</tr>
<tr>
<td>BOP ((%)</td>
<td>18 ± 20</td>
<td>13 ± 17</td>
<td>20 ± 18</td>
</tr>
</tbody>
</table>

♀Statistically significant at the level of \(p < 0.05\) with the Mann–Whitney–U-test for the differences in mean clinical parameters between baseline and 10 years. BOP, bleeding on probing; CAL, clinical attachment level; PPD, pocket probing depth.

![Fig. 1. Changes in CAL in the implants, between baseline and 5 years (left), and between baseline and 10 years (right) (see text). *\(p < 0.05\), Mann–Whitney U-test.](image1)

![Fig. 2. Changes in CAL in the reference teeth, between baseline and 5 years (left), and between baseline and 10 years (right).](image2)
Prevalence of peri-implantitis

Based on the definition used in this study, radiographic characteristics of peri-implantitis were observed after 5 and 10 years. Although the radiographic mean bone loss was <1 mm in all implants, there was bleeding upon probing in sites showing bone loss. In this case, the prevalence of peri-implantitis on the implant level was 8.9% after 5 years and 23.8% after 10 years. On the patient level it was 18.2% after 5 years and 30% after 10 years. This is in accordance with recently published data on other implant systems (Mir-Mari et al. 2012, Renvert et al. 2012). However, in this study, we detected horizontal or angular bone loss at the mesial, the distal, or both sites. No circumferential peri-implant loss of bone was determined. It is important to note that in this study the patients underwent a periodontal supportive treatment at regular intervals.

Survival and success rates of implants

After 10 years, two implants placed in the maxilla were lost yielding a survival rate of 92.3%. The survival rate in the mandible was 100%. No early failures were observed (Fig. 3). One further implant in the maxilla was lost after the observational period of the study. The data of the lost implants were evaluated after 5 years but not after 10 years.

Implant success was calculated considering the occurrence of peri-implantitis found within the cohort of implants investigated in this study. Thus, 91.1% and 76.2% of implants were successful after 5 and 10 years respectively.

Discussion

This prospective 10-year study analysed clinical parameters and peri-implant bone level changes of screw-type implants with internal hexagon placed in patients with a history of chronic periodontitis. Our clinical and radiographic results are in accordance with studies reporting effective long-term results of implant treatment in patients with periodontitis if an adequate infection control and an individualized maintenance programme are provided (Garcia-Bellosta et al. 2010, Al Zahrani 2008, Klokkevold & Han 2007, Jung et al. 2008, Evian et al. 2004, Fardal & Grytten 2013). Due to its macrostructure, this implant system is well suited for implantation in the fresh alveolus (Schulte et al. 1992). However, in the patients analysed here, it was used only for late implantations after finishing periodontal treatment and completely healed alveolar ridge.

To demonstrate periodontal conditions, we assessed clinical parameters in the complete dentition at baseline (the time point where the implants were loaded and provided with the prosthetic restorations), and at the 5- and 10-year examinations. Compared with baseline, the mean values of PPD, CAL and BOP were slightly higher after 5 years, and again after 10 years. This was also in accordance with the percentage of sites with PPD and CAL > 5 mm that was also higher after 5 years and after 10 years. Conversely, the percentage of sites with PPD and CAL 1–3 mm was similar to baseline after 5 years, showing higher levels at 10 years. This indicates a stable clinical situation in the patients between baseline and 5 years, however, with slight increments in the percentages of deeper periodontal pockets (PPD > 5 mm) and higher loss of attachment (CAL > 5 mm) after 10 years. This result is in accordance with studies analysing implants on a long-term basis that were placed in patients with previous periodontitis (Matarasso et al. 2010, Simonis et al. 2010, Rocuzzo et al. 2010, Simonis et al. 2010).

Table 4. Average differences in CAL, PPD and BOP between implants and reference teeth at baseline, at the 5-year and at the 10-year follow-up examinations

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Baseline</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPD (mm)</td>
<td>2.48 (0.03 to 0.23)</td>
<td>&lt;0.013*</td>
</tr>
<tr>
<td>CAL (mm)</td>
<td>0.27 (–0.11 to 0.15)</td>
<td>0.78</td>
</tr>
<tr>
<td>BOP (%)</td>
<td>0.66 (–0.09 to 0.12)</td>
<td>0.51</td>
</tr>
</tbody>
</table>

*Statistically significant at the level of p < 0.05 with the Wald Z-test. The regression coefficients (β) indicate the differences in the clinical parameters between reference teeth and implants over the measurement periods (5 and 10 years) from baseline. BOP, bleeding on probing; CAL, clinical attachment level; PPD, pocket probing depth.

Fig. 3. Kaplan–Meier cumulative survival rate (CSR) of the implants in the maxilla and mandible placed in patients with a history of periodontitis.
2012, Fardal & Grytten 2013). For example, in this study, there was an increase in BOP after 5 and 10 years, although the patients were well supported. An increase in bleeding is an indicator of the long-term oral hygiene practices and its relevance for maintaining healthy periodontal and peri-implant tissues (Mombelli & Lang 1998, Ferreira et al. 2006).

The main outcome variable of the study was the change in CAL of implants from baseline to 5, and from baseline to 10 years. We compared these data with the data of contra-lateral teeth, to analyse CAL in implants in comparison with CAL in natural teeth used as reference in the same patients. Our results show an increase in the mean CAL in implants from baseline to 10 years, and from baseline to 5 years, being significantly higher between baseline and 10 years. The analysis in the reference teeth did not show differences between baseline and 5 years. Our data are in accordance with the results of the periodontal parameters analysed by Ricci et al. (2004) in the same type of implants after 5 years, although different evaluation forms were used. The authors reported that in 71.4% of the implants probing depth did not exceed 3 mm, in 24.1% PPD was between 3 and 5 mm and in 4.5% PPD was greater than 5 mm (Ricci et al. 2004). We found similar data. In implants, the mean probing depth was 2.6 mm at baseline, 2.9 mm after 5 years and 3.3 mm after 10 years, in accordance with the 95.5% of sites with less than 5 mm reported by the study of Ricci et al. (2004).In this study, we also found lower PPD and CAL values in the reference teeth than in implants. Other studies assessing clinical parameters of peri-implant tissues in patients with varying severity of chronic periodontitis reported a greater loss of attachment ($p < 0.05$) around implants in the group with severe periodontitis compared to the no/mild periodontitis group (Ferreira et al. 2006, Alouf et al. 2009).

In addition, the clinical data were analysed using multilevel modelling, to correct for the difference in number of implants per patient and the dependency of the observations within each patient over time. The clinical parameter PPD showed differences between implants and reference teeth over time. The parameters CAL and BOP demonstrated no differences between implants and reference teeth over time.

According to the Kaplan–Meier method, the CSR was calculated to be 96.3%. The high CSR in our study is in accordance with the data reported by other authors on survival rates of same type of implants after 5 years (Krennmair et al. 2002, Krennmair & Waldenberger 2004, Ricci et al. 2004, Strietzel et al. 2004). In contrast, the CSR in our study was higher than the CSR reported in a retrospective study analysing the same type of implants after 5 years, with 91.08% for the maxilla and 89.1% for the mandible (Perry & Lenchewski 2004). Krennmair & Waldenberger (2004) retrospectively evaluated wide-diameter (5.5 mm) implants used for different forms of prosthetic restorations, placed in patients without a history of periodontal disease. The authors reported a CSR of 97.3% in the maxilla and 100% in the mandible, with two maxillary implants lost. The results of our study are similar, and both studies demonstrated only few implant losses in the maxilla after a prolonged period of time. This is in accordance with the majority of clinical studies of screw-type implants after 5 and 10 years. (Lekholm et al. 1999, Lambrecht et al. 2003, Strietzel et al. 2004, Blanes et al. 2007). However, it is important to note that the CSR of our analysis after 5 and 10 years in patients with a previous history of periodontitis is similar to the CSR data of the study of Krennmair & Waldenberger (2004) in non-periodontitis patients.

Peri-implant vertical bone loss is considered an important radiographic parameter for analysing treatment outcomes and long-term success (Lindhe & Meyle 2008, Meyle 2012). In this study, the evaluation of vertical bone loss was performed on intra-oral films using the parallel technique. In the study of Ricci et al. (2004), the radiographic results showed that 71.4% had less than 3 mm of crestal bone loss, with a mean mesial bone loss of 2.18 ± 1.6 mm and a mean distal bone loss of 2.16 ± 1.5 mm after 5 years. Our study showed small changes after 5 and 10 years, which is not in accordance with the results that the majority of studies of patients with previous history of chronic or aggressive periodontitis have reported (Schou et al. 2006, Mengel et al. 2007, Schou 2008, Matarasso et al. 2010). However, our data are in accordance with the data reported in a clinical and radiographic prospective study of implant treatment outcome in periodontally susceptible and non-susceptible patients (De Boever et al. 2009). After an average of 5 years, the authors reported an average marginal bone loss for all implants of 0.12 ± 0.71 mm on the mesial side and 0.11 ± 0.68 mm on the distal side. Specifically, in the group with aggressive periodontitis, the bone loss per year was 0.17 mm. The main difference between this and our study is that in the study of De Boever et al. (2009) patients were treated with non-submerged Straumann implants. This is less than the reported bone loss by Mengel et al. (2007), with an average of 2.07 mm in the first year and a total of 1.3 mm in the subsequent 9 years (Mengel et al. 2007). Our data confirm the lower bone loss levels found in the prospective study of De Boever et al. (2009).

The percentage of peri-implantitis observed in this study is in accordance with recently published data on other implant systems (Mir-Mari et al. 2012, Renvert et al. 2012). As it is known that the absence of maintenance treatment is associated with a higher incidence of peri-implantitis, it is important to note that in this study the patients underwent periodontal supportive treatment at regular intervals (Costa et al. 2012).

Conclusions
The results of this study demonstrate that patients previously treated for chronic periodontitis and thereafter with screw-type implants with internal hexagon showed stable peri-implant variables and survival rates, and stable radiographic bone levels after 5 and 10 years, if patients were engaged in a regular periodontal maintenance programme. Nevertheless, there was a higher loss of CAL around the implants than around the natural reference teeth, although not clinically relevant.
The authors thank the colleagues of the Department of Periodontology, Justus-Liebig-University of Giessen, who contributed to this study, especially Mrs. V. Petsch, R. Wilhelm and P. Pellizzi. They also thank Dr. R.H. Boedeker (Institute of Medical Statistics, University of Giessen) for his valuable statistical assistance.

Acknowledgements

References


Clinical Relevance

**Scientific rationale for the study:** the use of osseointegrated implants in patients with a history of periodontitis is continuously increasing, although there is still a lack of long-term data for this type of patient.

**Principal findings:** there is a stable peri-implant and periodontal situation after 5 and 10 years under the premise that patients with previous periodontitis receive regular, supportive periodontal treatment.

**Practical implications:** all patients with a history of periodontitis undergoing implant therapy must be included and treated in a long-term periodontal supportive treatment programme.