Fixed Implant-Retained Rehabilitation of the Edentulous Maxilla: 11-Year Results of a Prospective Study

Christian Mertens, DDS;* Helmut G. Steveling, DDS;† Kathrin Stucke;‡ Bernadette Pretzl, DDS;§ Amelie Meyer-Bäumer, DDS§

ABSTRACT

Objectives: The aim of the present study was to assess long-term survival and success rates of implants in the edentulous maxilla restored with an implant-supported fixed prosthesis.

Materials and Methods: Seventeen edentulous patients received six to eight implants and implant-supported fixed prostheses by one surgeon. Yearly recalls were conducted by two examiners over a period of 11 years. Survival and success rates (biological complications) were determined; marginal bone loss was examined radiographically. Furthermore, microbiological tests as well as test for interleukin-1 composite genotype were assessed and potential risk factors were evaluated.

Results: After a mean time of 11.26 years, 15 patients of 17 could be reexamined. Out of 94 implants, three were lost in one patient. Mean marginal bone loss reached 0.88 mm, two patients (at seven implants) showed bone loss of ≥3.2 mm. Survival rate of implants reached 96.8%. Success rates on implant level hit 92.6% according to the criteria of Albrektsson and colleagues and 83.0% in accordance with Karoussis and colleagues. One prosthesis had to be renewed.

Conclusion: Within the limitation of this study, restoration of the edentulous maxilla with an implant-supported fixed prosthesis represents an effective tool for rehabilitation over a period of 11 years.

KEY WORDS: dental implants, edentulous maxilla, prosthetic rehabilitation, success rate, survival rate

INTRODUCTION

Restorative reconstructions performed on implants show high success and survival rates.[1] Many studies document that reconstruction by implant-supported single-unit crowns or fixed partial bridges depicts a persistent preventive tool to rehabilitate partially edentulous patients.[1–6]

In edentulous patients, a low failure rate of 3.3% for implant-supported overdentures in the mandibula could be found over a period of 3 years. Whereas the results for implant-supported overdentures in the maxilla seem to be less favorable with a failure rate of 27.6%.[7] Further, long-term data of implant-supported fixed prostheses or overdentures in edentulous mandibles are available and present a reliable solution for rehabilitation.[8,9] On the other hand, prospective long-term results over a period of 10 years or more of such prosthetic reconstructions in the edentulous maxilla are rare.[10]

Factors contributing to implant loss and biological complications are discussed in the literature. However, randomized prospective long-time studies evaluating risk factors and their connection to implant treatment are rare. Some patient-related factors such as smoking,[11–15] diabetes mellitus,[16] oral hygiene standards,[17] compliance to supportive periodontal treatment (SPT),[18] interleukin (IL)-1 composite genotype,[19] and bacterial load could be detected as risk factors advancing

*Senior resident, Department of Oral and Maxillofacial Surgery, University Hospital Heidelberg, Heidelberg, Germany; †private practice, Gernsbach, Germany; ‡biostatistician, Institute of Medical Biometrics and Informatics, University of Heidelberg, Heidelberg, Germany; §senior resident, Section of Periodontology, Department of Conservative Dentistry, University Hospital Heidelberg, Heidelberg, Germany

Reprint requests: Dr. Christian Mertens, Department of Oral and Maxillofacial Surgery, University Hospital Heidelberg, Im Neuenheimer Feld 400, D-69120 Heidelberg, Germany; e-mail: christian.mertens@med.uni-heidelberg.de

The authors declare that there are no conflicts of interest in this study.

DOI 10.1111/j.1708-8208.2011.00434.x

the development of peri-implantitis and implant loss. Further, implant-related factors like implant surface,[20] implant position,[7,21] surgical approach used during implant insertion,[22,23] implant type, or type of reconstruction[24,25] may influence the prognosis.

The aim of the present prospective study was to assess long-term survival and success rates in edentulous patients reconstructed by an implant-fixed bridge in the maxilla. Furthermore, potential risk factors for implant loss or biological complications should be detected.

MATERIALS AND METHODS

Patients

The study was approved by the Institutional Review Board for Human Studies of the Medical Faculty of Heidelberg University in 1998 (Application# 260/98). Patients were informed on risks and benefits as well as the procedures of the study and gave written informed consent.

All patients participating in this prospective study were recruited consecutively at the Department of Oral and Maxillofacial Surgery of the University of Heidelberg between January 1999 and October 1999. All of them had to comply with the following inclusion criteria:

- 18–75 years of age;
- edentulous maxilla;
- sufficient bone-to-support implants of at least 9 mm length; no need for augmentation;
- type 1–3 bone quality according to the Lekholm and Zarb classification;
- at least 6 months between tooth extraction and implant placement;
- no systemic disease or condition as well as no systemic medication of corticosteroids or any further medication that could compromise postoperative healing or osseointegration.

Surgical and Prosthetic Procedure

All implants were placed by the same experienced oral surgeon between January and October 1999 in one stage surgical procedures. Each patient received six to eight implants (TiOblast™, Astra Tech AB, Mölndal, Sweden) during a standardized surgical procedure under local anesthesia. The number and location of implants depended on the anatomic and morphologic conditions of the bone.[26] All implants had a diameter of 3.5 or 4.0 mm, a length of 8 to 17 mm, and were of moderately rough titanium, screw shaped, and parallel walled. The fixtures presented a coronal portion equipped with minute threads (MicroThread™, Astra Tech AB). Patients received prophylactic antibiotics 1 hour before surgery, but no postoperative antibiotics.

Six months after implant surgery, prosthetic rehabilitation of the maxilla followed. Impressions were taken on abutment level after placement of the definitive one-piece titanium abutments (Uni-abutment™, Astra Tech AB). Then all patients received a one-piece, fixed, screw-retained reconstruction (Figure 1 A and B). To avoid mucosal irritation by impaired cleaning, the base of the full-arch restoration provided a convex, bridge-like design, just slightly contacting the oral mucosa. After setting the prosthesis, patients received oral hygiene instructions.

Follow-Up and Reexamination

After 6 and 12 months, and thereafter at yearly intervals, patients showed up for recall. During each follow-up

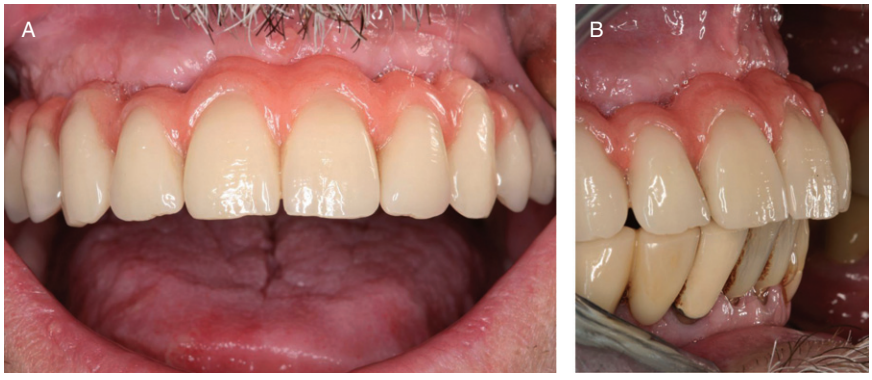

Figure 1 Full-arch, fixed, screw-retained prosthetic reconstruction.

session modified bleeding index (MBI) and modified plaque index (MPI)[27] were assessed at four sites per implant (buccal, lingual, mesial, and distal). Also, each patient was reinstructed and remotivated to an effective individual plaque control. Professional tooth and implant cleaning followed.

Reexamination 11 years after implant setting included:

- Self-reported comprehensive smoking history. Accordingly, patients were categorized in two classes: current and former smokers/non-smokers. Patients who had quit smoking at least 5 years before implant insertion were classified as former smokers[28];
- MBI and MPI[27];
- Probing pocket depth (PPD) to the nearest 1 mm using a manual periodontal probe (PCPUNC 15, Hu-Friedy, Chicago, IL, USA) at four sites per implant;
- Bleeding on probing (BoP) after 30 seconds and suppuration on probing;
- Mobility. To test mobility of implants, dentures were unscrewed. To classify as non-mobile, an implant had to resist torquing the abutment to 20 Ncm;
- Microbiological test (ParoCheck 20, Greiner Bio-One, Frickenhausen, Germany). After supragingival plaque removal pooled subgingival plaque samples were taken from all implants of each individual patient. Samples were obtained using sterile paper points, which were inserted into the deepest pocket of each implant until resistance was met and left there for 20 seconds. These paper points were then pooled together into a single transport container and sent to a laboratory;
- Test for IL-1 composite genotype using a test kit (GenoType IL-1, Hain Lifescience GmbH, Nehren, Germany). To sample cells, a foam swab was moved over cheek mucosa for 20 seconds and then sent to the laboratory for analysis. A patient was classified as IL-1 composite genotype positive,[29] if IL-1A allele –C889T (rs1800587) and IL-1B allele +C3953T (rs1143634) were present;
- Periapical radiographs of each implant.

Radiographic Examination

To determine bone loss, periapical radiographs were taken after implant surgery, prosthetic setting (= radiographic baseline), and each year at the follow-up sessions. All radiographs were analyzed using the computer program Friacom® Dental Office 2.5 (Friadent, Mannheim, Germany) in a darkened room. At mesial and distal sites of each implant, the distances between the implant shoulder and the first visible bone-implant contact were measured as well as the implant length. Afterwards, the amount of bone loss in millimeters was assessed by setting the known implant length in correlation to the measured distance. All analyses were performed by one independent examiner.

Definition of Success/Survival

Survival represented the main outcome variable of this study and was defined as implant still in function. In accordance to the criteria defined by Albrektsson and colleagues[30] success rates were analyzed as second outcome variable according to the following criteria:

- Absence of persistent signs/symptoms such as pain, infection, neuropathy, paresthesia, and violation of vital structures;
- Absence of implant mobility;
- Absence of continuous peri-implant radiolucency;
- Annual vertical bone loss should not exceed 0.2 mm.

Furthermore, the more rigorous criteria by Karoussis and colleagues[31] were used to define success rates being stricter in determination of peri-implantitis/implant success:

- Absence of mobility[32];
- Absence of persistent subjective complaints (pain, foreign body sensation, and/or dysesthesia)[32];
- No PPD > 5 mm[33,34];
- No PPD = 5 mm and BoP[34];
- Absence of a continuous radiolucency around the implant[32];
- Annual vertical bone loss should not exceed 0.2 mm.[30,35]

Statistical Analysis

Descriptive statistics for all clinical and radiographic parameters at patient and at implant level were performed using the computer program SPSS 18 (SPSS Inc., Chicago, IL, USA). Furthermore, to estimate survival rates of implants, a Kaplan–Meier analysis was used.[36]

TABLE 1 Patient's Characteristics and Implant Loss Rates on Patient Level

			Success Rates according to	
	Patients $n = 15$ (%)	Survival Rate $n = 14$ (93.3%)	Albrektsson et al. $n = 13$ (86.7%)	Karoussis et al. $n = 8$ (53.3%)
Sex				
Female	10 (66.7)	9 (90.0)	9 (90.0)	6 (60.0)
Male	5 (33.3)	5 (100.0)	4 (80.0)	2 (40.0)
Smoking status				
Non-/former smoker	9 (60.0)	9 (100.0)	9 (100.0)	6 (66.7)
Current smoker	6 (40.0)	5 (83.3)	4 (66.7)	2 (33.3)
IL-1 composite genotype				
Positive	4 (26.7)	3 (75)	3 (75.0)	1 (25)
Negative	11 (73.3)	11 (100)	10 (90.1)	7 (63.6)
Age (years)	41–69 (55.3 ± 7.853)			
Time of follow-up (years)	10.42–12.25 (11.26 ± 5.261)			

IL-1, interleukin-1.

Multilevel regression analysis was modeled by an independent statistician using the program SAS® 9.1 (SAS Institute, Cary, NC, USA). Because the number of patients was relatively low (15 patients at final follow-up visit with 94 implants) and very few implant losses occurred, valuators (risk factor) analysis could not be assessed. Even by reducing the amount of variables results were not reliable. Thus, only descriptive statistics are presented in this paper.

RESULTS

Patients

Seventeen patients were included in this prospective study. During a mean follow-up time of 11.26 years (range 10.42–12.25 years) after implant setting, one of the 17 patients died, another one did not show up for reexamination because of emigration. Therefore, the responder rate adds up to 88.2% (15 patients) (Figure 2).

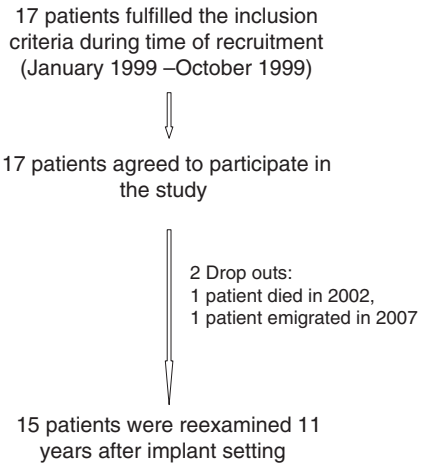

Figure 2 Recruitment of patients.

At initiation of the study, patients were 41 to 69 years old (mean 55.3 years ± 7.9). All of them were edentulous in the maxilla and showed bone loss of ≥30% in the opposite jaw. Ten patients (66.7%) were female, 40% were smokers, and four patients (26.7%) showed a positive IL-1 composite genotype (Table 1). To ensure stable occlusion, all patients were adequately supplied in the mandible at the time of implant surgery (Table 2).

Implants

In total, 94 implants were set in 15 patients. Each patient received six to eight implants in the maxilla. Fifty-six implants were set in the frontal region, 38 in the lateral area. Length of implants was 9 to 17 mm; diameter was either 3.5 (75 implants) or 4.0 mm (19 implants). Distribution of placed implants according to position and length is given in Table 3.

TABLE 2 Kind of Prosthetic Rehabilitation of the Lower Jaw at Time of Implant Placement

Opposing Denture	Number of Patients
Natural teeth	3
Removable prostheses	9
Fixed partial prostheses	2
Implant-supported dentures	1
Complete dentures	2

TABLE 3 Distribution of Placed Implants ($n = 94$) according to the Position in the Maxilla and Length of Implants

Implant length (mm)	Frontal Region			Lateral Region					
	1	2	3	4	5	6	7	Total	%
9	1	2	0	8	9	1	2	23	24.47
11	8	1	3	4	8	1	0	25	26.60
13	12	1	12	4	1	0	0	30	31.91
15	3	3	7	0	0	0	0	13	13.83
17	2	0	1	0	0	0	0	3	3.19
Total	26	7	23	16	18	2	2	94	100
%	27.66	7.45	24.47	17.02	19.14	2.13	2.13	100	

In most cases, the MBI was of degree 0 (75.8%) or 1 (22%) with a mean value of 0.26. In two patients, an MBI of degree 2 could be found at one implant each (2.2%). Most implants (84.6%) showed satisfactory oral hygiene (grade 0 and 1), with a mean MPI value of 0.69 (grade 0: 42 implants, grade 1: 35 implants; grade 2: 14 implants). Mean implant pocket depth was 3.82 mm; range was 3–9 mm (Figure 3).

Implant Survival

Only one of the fifteen patients lost three implants during time of follow-up resulting in a patient-related survival rate of 93.3%. The patient was female, with 41 years of age at the time of implant setting the youngest patient, smoker, and IL-1 composite genotype positive (see Table 1). She had natural teeth in the opposing jaw.

Hence, survival rate on implant level reached 96.8%. Three implants out of 94 were lost (Figure 4). One of these was lost during the healing period, the other two 9 years after insertion because of peri-implantitis. Two of them were placed in the lateral region, one in the frontal area. Diameter of all lost implants was 3.5 mm, length was 11 and 13 mm, respectively (Table 4).

Success Rates

Success Rates on Patient Level. During the follow-up period, two out of 15 patients showed implants failing the success criteria by Albrektsson and colleagues,[30] which results in a success rate on patient level of 86.7%. Both patients, who lost more than 3.2 mm of bone at implants, were smokers and

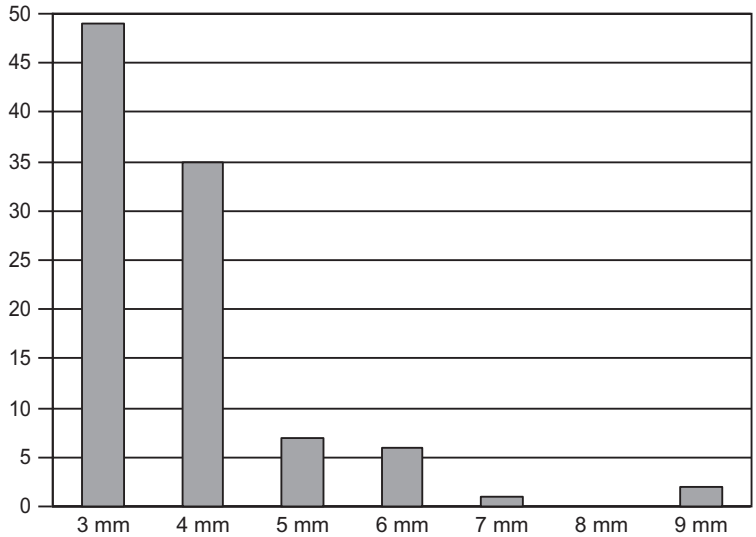

Figure 3 Distribution of detected peri-implant pocket depths in percent.

TABLE 4 Implant Distribution and Survival/Success Rates on Implant Level

			Success Rates according to	
	Implant Distribution *n* = 94 (%)	Survival Rate *n* = 91 (96.8%)	Albrektsson et al. *n* = 87 (92.6%)	Karoussis et al. *n* = 16 (83.0%)
Sex				
Female	63 (67.0)	60 (95.2)	60 (95.2)	53 (84.1)
Male	31 (33.0)	31 (100.0)	27 (87.1)	25 (80.7)
Smoking status				
Non-/former smoker	57 (60.6)	57 (100.0)	57 (100.0)	52 (91.2)
Current smoker	37 (39.4)	34 (91.9)	30 (81.1)	26 (70.3)
IL-1 composite genotype				
Positive	25 (26.6)	22 (88.0)	22 (88.0)	18 (72.0)
Negative	69 (73.4)	69 (100.0)	65 (94.2)	60 (87.0)
Location				
Frontal region	56 (59.6)	55 (98.2)	53 (94.6)	48 (85.7)
Lateral region	38 (40.4)	34 (89.5)	34 (89.5)	30 (79.0)
Implant length (mm)				
9	23 (24.5)	23 (100.0)	22 (95.7)	20 (87.0)
11	25 (26.6)	23 (92.0)	23 (92.0)	21 (84.0)
13	30 (31.9)	29 (96.7)	27 (90.0)	24 (80.0)
15	13 (13.8)	13 (100.0)	12 (92.3)	11 (84.6)
17	3 (3.2)	3 (100.0)	3 (100.0)	2 (66.7)
Implant diameter (mm)				
3.5	75 (79.8)	72 (96.0)	68 (90.7)	60 (80.0)
4.0	19 (20.2)	19 (100.0)	19 (100.0)	18 (94.7)

under 50 years of age when implants were set (see Table 1).

A lower success rate on patient level (53.3%) was determined when adhering to the criteria of Karoussis and colleagues[31] Nonfulfillment of success criteria was documented more often in current smokers than in former or non-smokers (66.7 vs 33.3%). Additionally, implants in IL-1 composite genotype positive patients failed the criteria more frequently compared with IL-1 composite genotype negative patients (63.6 vs 25.0%). Female patients presented a higher success rate than males (see Table 1).

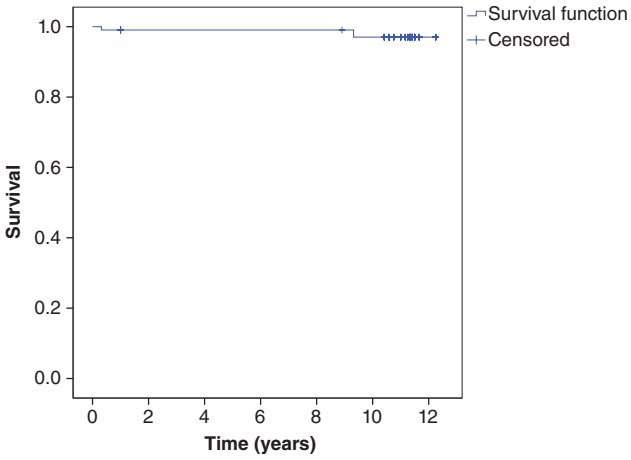

Figure 4 Kaplan–Meier estimates of implant survival in 17 patients (one patient died after the 1 year examination, another emigrated and reported of no implant loss after 11 years via mail).

Success Rates on Implant Level. On implant level, success rates added up to 92.6% according to the criteria by Albrektsson and colleagues.[30] Seven implants presented marginal bone loss of 3.2 mm or more including the three lost implants. Mean bone loss after 11 years was 0.56 mm (SD 1.28 mm, range 0.0–7.76 mm). After 5 years of observation, mean bone loss was 0.25 mm (SD 0.66 mm, range 0.0–4.01 mm) and after 8 years it adds up to 0.3 mm (SD 0.72 mm, range 0.0–5.76 mm). Progression of bone loss at 5, 8, and 11 years of follow-up are presented in Figure 5. Using the criteria according to and colleagues,[31] success rates decreased to 83.0%.

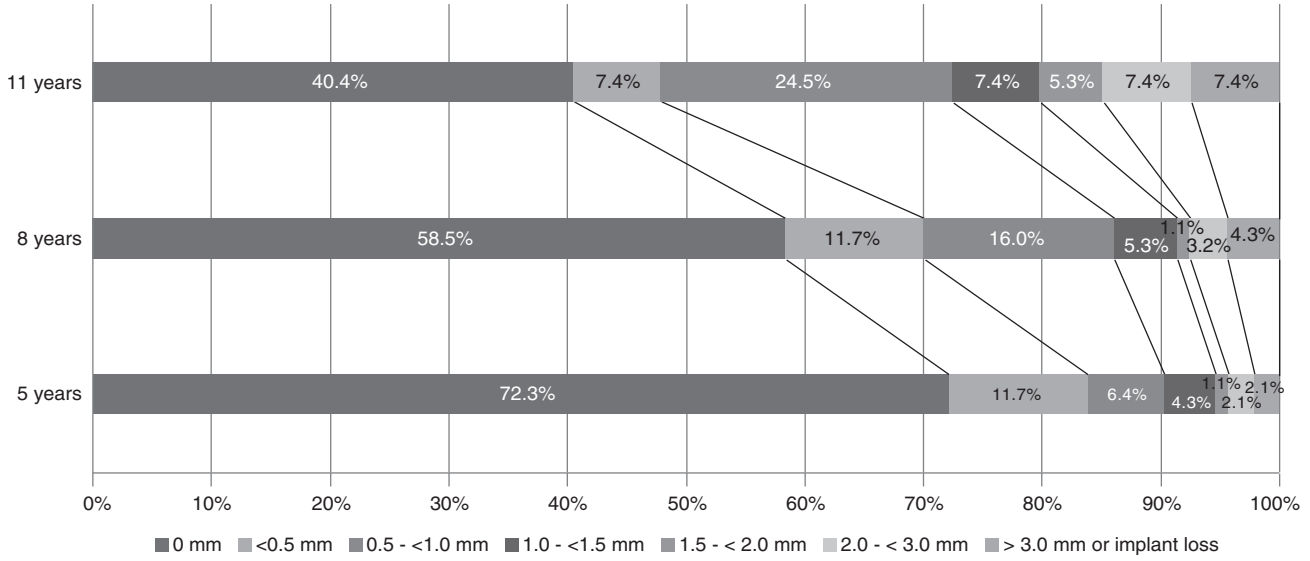

Figure 5 Distribution of implant-related marginal bone loss after 5, 8, and 11 years in function.

With regard to patient-related factors, similar tendencies could be detected on implant level: females and non-/former smokers showed higher success rates than males and smokers. Furthermore, patients exhibiting a positive IL-1 composite genotype showed more often biological complications (see Table 4).

Also, the implant-related factors location, implant diameter, and implant length were assessed. Improved success rates could be found in implants with a diameter of 4.0 mm compared with those with 3.5 mm (100.0 vs 96.0% and 94.7 vs 80.0%, respectively) and in implants set in the frontal region. Regarding the length of implants, complications were distributed uniformly (see Table 4).

Microbiological Findings

Eleven years after implant setting, a microbiological test was conducted in each patient (ParoCheck 20). The periodontal pathogene *Aggregatibacter actinomycetemcomitans* could not be detected in any patient. Some bacteria like *Treponema denticola* or *Fusobacterium nucleatum* were found in nearly all patients; *Porphyromonas gingivalis* and *Prevotella intermedia* were quantified in few patients (Table 5). Significant correlations between increased mean pocket depth and presence of only one specific bacteria (*Actinomyces odontolyticus*) could be detected ($p = .021$). Comparing the microbiological flora in patients with biological complications with those without complications did not result in any differences. Also, the patient who had lost three implants (number 11) showed no significant accumulation of pathogens.

Survival of Prosthetic Reconstruction

At reexamination, 14 out of 15 patients still wore the same fixed implant-retained bridge, resulting in a survival rate of reconstructions of 93.3%. One patient received a new prosthesis after replacement of two implants lost after 9 years in function. During the whole follow-up time, just few prosthetic complications could be assessed (see Table 6). No serious technical complications such as abutment or metal framework fractures occurred during the observation period.

DISCUSSION

The aim of the present study was to assess long-term success and survival rates in the edentulous maxilla reconstructed with an implant-supported fixed prosthesis.

In our prospective study, a long-term implant survival rate of 93.3% could be determined on patient level. Also, high success rates of 86.7% according to the criteria of Albrektsson and colleagues[30] and a lower one of 53.3% according to the criteria of Karoussis and colleagues,[31] were detected. Furthermore, just few prosthetic complications occurred.

To minimize confounding factors, implants with the same surface were set in all patients. Also, only

TABLE 5 Results of Microbiologic Probing per Patient Analyzed after 11 Years of Function and Correlation of Bacterial Load to Increased Mean Periodontal Probing Depth

	Patient Number															
Bacteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	*p*
Aggregatibacter actinomycetemcomitans	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Actinomyces viscosus	(+)	++	++	+	(+)	+++	—	+	++	—	+	—	—	++	—	0.346
Tannerella forsythensis	+++	+++	—	+	+++	+	++	+++	—	+	++	+	++	—	+++	0.842
Campylobacter rectus	++	++	++	—	++	—	—	—	—	—	+	—	—	—	—	0.215
Treponema denticola	+++	+++	++	—	+++	+++	+++	++	++	+++	++	+	—	—	+++	0.078
Eikenella corrodens	+++	—	—	—	—	(+)	—	—	+++	—	—	—	—	++	—	0.772
Prevotella intermedia	+	+++	+++	—	—	++	—	—	—	—	—	—	—	—	—	0.361
Peptostreptococcus micros	++	+	++	—	++	(+)	(+)	+	++	+	—	—	(+)	—	—	0.710
Porphyromonas gingivalis	++	+++	—	—	+++	—	—	+++	—	––	+	—	—	—	++	0.338
Fusobacterium nucleatum	+++	+++	+++	+++	+++	+++	++	+++	+++	+++	+++	++	++	+++	+++	0.340
Actinomyces odontolyticus	+++	+++	+	++	++	+++	—	++	++	++	+++	(+)	+++	++	+	0.021*
Capnocytophaga gingivalis	++	++	+++	++	++	+++	—	—	+++	(+)	+	—	—	+++	—	0.344
Campylobacter concisus	+	—	+	—	—	+	—	—	—	—	—	—	—	—	—	0.992
Eubacterium nodatum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	–
Streptococcus constellatus	++	—	—	—	—	++	—	—	++	—	(+)	—	(+)	(+)	—	0.771
Campylobacter gracilis	++	++	(+)	(+)	++	+++	—	+	++	++	—	—	—	+	+	0.989
Streptococcus mitis	+++	++	+++	+++	++	+++	—	+	+++	++	—	—	++	+++	—	0.248
Prevotella nigrescens	++	—	++	+	—	+	++	(+)	—	++	++	—	++	++	—	0.531
Streptococcus gordonii	+++	+++	+	++	+	+++	(+)	++	++	++	+	(+)	++	++	+	0.191
Veillonella parvula	+++	+++	+++	+++	+++	+++	+	+++	+++	+++	++	+	++	+++	+++	0.152

*Significant correlation.

rehabilitations of upper jaws were included, and all subjects received the same prosthetic restoration. Nevertheless, by interpreting the data, the low number of included patients has to be considered, which represents a strong limitation of the results of this study. Furthermore, it remains uncertain whether all patients were periodontally compromised, and therefore, comparison with other studies has to be interpreted with caution.

TABLE 6 Distribution of Mechanical Complications during 11 Years of Function

	Number of Events							
	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years	11 Years	Total
Chipping of acrylic teeth	0	3	0	0	2	0	0	5
Aging of acrylic base	0	1	2	3	1	0	0	7
Abutment fractures	0	0	0	0	0	0	0	0
Abutment screw fractures/screw loosening	0	0	0	0	0	0	0	0
Metal framework fractures	0	0	0	0	0	0	0	0

Indeed, all patients, who still possessed teeth in the lower jaw at baseline, presented a marginal bone loss of 30% or more, but neither periodontal pocket depths nor attachment levels were determined at baseline or follow-up recalls. Therefore, a clear diagnosis of periodontitis is missing, and a correct classification of the presented clientele in periodontally healthy or compromised patients is considered impossible.

Survival Rates

Several 10-year longitudinal studies have been published on the implant system used in this study (Astra Tech TiOblast implant surface), but none of them has been focused on the edentulous maxilla.[37–40] A recent observation of implant-supported fixed prostheses in the maxilla with the TiUnite Branemark System[41,42] presents comparable results (93.4 and 97.3%, respectively) to our data (96.8%), but the observation period is just 5 years. Another retrospective study by Astrand and colleagues[10] showed data on edentulous jaws over a period of 20 years. But only seven of the 23 included prostheses were set in the maxilla (27 included implants). The survival rate of 99.2% in this study was slightly increased compared with our data. Results of prospective studies over 10 years in the edentulous maxilla are, to our best knowledge, missing.

Comparing data of studies including patients rehabilitated with implant-supported fixed prostheses in partially edentulous jaws, similar survival rates can be found.[8,9] With survival rates of 93.3% (at patient level) and 96.8% (at implant level), respectively, over a period of 11 years, our results slightly exceed the findings in a recent prospective longitudinal study with a follow-up time of 10 years, where survival rates of 94.2% in patients with a moderate form of periodontitis and of 90.0% in patients with severe periodontitis could be detected.[18] Other recent retrospective long-term studies showed survival rates of 90.0[5] and 89.2%,[6] and further longitudinal studies presented similar results.[13,31,43] But all patients in these studies were periodontally compromised and just partially edentulous; in our study, the patients were edentulous in the maxilla and periodontal status is unclear.

Factors influencing implant loss could not be calculated, because of the low number of patients included in this study and the rare event of implant loss. The person who lost all three implants was female, currently smoking, and IL-1 composite genotype positive. With 41 years of age at time of implant setting, she represented the youngest patient. In a recent retrospective study by Aglietta and colleagues,[11] smoking could be detected as one significant factor for implant loss, especially in a periodontally compromised patient (PCP). Aside, Feloutzis and colleagues[19] revealed that IL-1 composite genotype positive smoking patients yielded a higher risk for peri-implant bone loss than IL-1 composite genotype positive non-smokers. In a prospective study by Mengel and colleagues,[44] patients with generalized aggressive periodontitis (GAgP) presented a decreased survival rate of 83.3% as compared with periodontally healthy patient (PHP). Whether the patient experiencing implant loss in our study had a GAgP at baseline could not be proven retrospectively, because former radiographs or data were not available.[45] But judging by the tremendous tooth loss at that age, as well as the bone loss in the mandible, it can be assumed that the patient suffered from GAgP.

Success Rates

Comparison of available success rates remains difficult because an international non-equivoque definition of "peri-implantitis" is lacking.[18] Therefore, we chose the criteria by Albrektsson and colleagues,[30] to define success. Accordingly, implants with marginal bone loss of ≥3.2 mm at least at one site were considered as a lack of success (bone loss of 1.2 mm in the first year; in the following years, 0.2 mm).

Of the reexamined subjects (two patients), 13.3% showed marginal bone loss around their implants (success rate of 86.7% at patient level). Seven (7.4%) out of 94 implants presented marginal bone loss of ≥3.2 mm (success rate of 92.6% at implant level). In comparable long-term studies, which also chose the criteria by Albrektsson and colleagues,[30] similar complication rates were documented in PHPs. Simonis and colleagues[6] reported an occurrence of peri-implantitis in 10.5% of all implants in PHP, whereas in PCP, the rate of biological complications increased (16.9%).

Furthermore, the more rigorous criteria by Karoussis and colleagues[31] were chosen for a second analysis of implant success. A real decline of implant success can be noticed when comparing the success rates according to the criteria by Albrektsson and colleagues[30] with those of Karoussis and colleagues.[31] The reason for this is the high amount of implants with increased pocket depths of 5 mm or more. Almost half of all patients (53.3%) showed peri-implantitis according to Karoussis' criteria.

Regarding the implant level, 83.0% of all implants could be determined as successful. In the study by Karoussis and colleagues,[31] results in patients with a history of periodontitis showed less successful implants (52.4%), whereas the success rate of 79.1% in PHP rather matches our data.

Reporting both success on patient and on implant level shows the spectrum of possible interpretations: every second patient failed Karoussis success criteria over the study period of 11 years, while on implant level, only every fifth implant failed these criteria.

As described in other studies, not only implant loss but also biological complications seem to be more common in smokers,[11,13,31,46] in patients not compliant with SPT,[18] in patients with GAgP,[44] or IL-1 genotype positive patients.[19] Additionally, implant-related factors such as implant surface, location, implant length, or diameter are discussed as being responsible for implant failure or success.

In this study, a tendency was found for the patient-related factors, smoking and IL-1 composite genotype, to affect implant success as well as the implant-related factors, implant diameter and location. Smokers and IL-1 composite genotype positive patients more often showed biological complications than non-smokers and IL-1 composite genotype negative subjects. Also, implants located in the lateral region and with wider diameter turned out to be more successful.

Microbiological Findings

In the present report, microbiological tests could not detect any significant differences in the microbiological flora in patients with and without implant loss, which might be a result of the low amount of patients included and the rare event "implant loss."

A correlation of *Actinomyces odontolyticus* and deepened implant pockets could be detected but has to be interpreted with caution because of the low patients number. *Aggregatibacter actinomycetemcomitans* could not be detected in any of the patients in contrast to the results by Persson and colleagues.[47]

Prosthetic Complications

Prosthetic complications were solely related to the acrylic parts of the prostheses (e.g., resin fractures). The complication rate coincides with a similar study in which the same fixed screw-retained suprastructure was used.[48] The patient who needed prosthesis replacement was the same patient who lost the three implants. Consequently, in this case, a new implantologic as well as prosthetic treatment was required because of the insufficient number and distribution of implants.

CONCLUSION

Within the limitations of this study, restoration of an edentulous maxilla with an implant-supported fixed prosthesis on six to eight implants presents an effective tool for rehabilitation over a period of 10 years. High success and survival rates could be determined, whereas an evaluation of potential risk factors could not have been performed because of the low number of patients.

ACKNOWLEDGMENTS

We thank Prof. Dr. Dr. T.-S. Kim for her support. Furthermore, the study was supported by Tech AB, Mölndal, Sweden. Bioscientia, Ingelheim, Germany, provided the kits for IL-1 composite genotype tests.

REFERENCES

1. Pjetursson BE, Tan K, Lang NP, Bragger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. Clin Oral Implants Res 2004; 15:625–642.
2. Bragger U, Karoussis I, Persson R, Pjetursson B, Salvi G, Lang N. Technical and biological complications/failures with single crowns and fixed partial dentures on implants: a 10-year prospective cohort study. Clin Oral Implants Res 2005; 16:326–334.
3. Jung RE, Pjetursson BE, Glauser R, Zembic A, Zwahlen M, Lang NP. A systematic review of the 5-year survival and complication rates of implant-supported single crowns. Clin Oral Implants Res 2008; 19:119–130.
4. Lang NP, Pjetursson BE, Tan K, Bragger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. II. Combined tooth – implant-supported FPDs. Clin Oral Implants Res 2004; 15:643–653.
5. Matarasso S, Rasperini G, Iorio Siciliano V, Salvi GE, Lang NP, Aglietta M. A 10-year retrospective analysis of radiographic bone-level changes of implants supporting single-unit crowns in periodontally compromised vs. periodontally healthy patients. Clin Oral Implants Res 2010; 21:898–903.
6. Simonis P, Dufour T, Tenenbaum H. Long-term implant survival and success: a 10–16-year follow-up of non-submerged dental implants. Clin Oral Implants Res 2010; 21:772–777.

7. Hutton JE, Heath MR, Chai JY, et al. Factors related to success and failure rates at 3-year follow-up in a multicenter study of overdentures supported by Branemark implants. Int J Oral Maxillofac Implants 1995; 10:33–42.
8. Lindquist LW, Carlsson GE, Jemt T. A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. Clin Oral Implants Res 1996; 7:329–336.
9. Quirynen M, Alsaadi G, Pauwels M, Haffajee A, van Steenberghe D, Naert I. Microbiological and clinical outcomes and patient satisfaction for two treatment options in the edentulous lower jaw after 10 years of function. Clin Oral Implants Res 2005; 16:277–287.
10. Astrand P, Ahlqvist J, Gunne J, Nilson H. Implant treatment of patients with edentulous jaws: a 20-year follow-up. Clin Implant Dent Relat Res 2008; 10:207–217.
11. Aglietta M, Siciliano VI, Rasperini G, Cafiero C, Lang NP, Salvi GE. A 10-year retrospective analysis of marginal bone-level changes around implants in periodontally healthy and periodontally compromised tobacco smokers. Clin Oral Implants Res 2011; 22:47–53.
12. Heitz-Mayfield LJ, Huynh-Ba G. History of treated periodontitis and smoking as risks for implant therapy. Int J Oral Maxillofac Implants 2009; 24 (Suppl):39–68.
13. Roos-Jansaker AM, Lindahl C, Renvert H, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part I: implant loss and associations to various factors. J Clin Periodontol 2006; 33:283–289.
14. Roos-Jansaker AM, Renvert H, Lindahl C, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part III: factors associated with peri-implant lesions. J Clin Periodontol 2006; 33:296–301.
15. Strietzel FP, Reichart PA, Kale A, Kulkarni M, Wegner B, Kuchler I. Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. J Clin Periodontol 2007; 34:523–544.
16. Mombelli A, Cionca N. Systemic diseases affecting osseointegration therapy. Clin Oral Implants Res 2006; 17 (Suppl 2):97–103.
17. Serino G, Strom C. Peri-implantitis in partially edentulous patients: association with inadequate plaque control. Clin Oral Implants Res 2009; 20:169–174.
18. Roccuzzo M, De Angelis N, Bonino L, Aglietta M. Ten-year results of a three-arm prospective cohort study on implants in periodontally compromised patients. Part 1: implant loss and radiographic bone loss. Clin Oral Implants Res 2010; 21:490–496.
19. Feloutzis A, Lang NP, Tonetti MS, et al. IL-1 gene polymorphism and smoking as risk factors for peri-implant bone loss in a well-maintained population. Clin Oral Implants Res 2003; 14:10–17.
20. Berglundh T, Gotfredsen K, Zitzmann NU, Lang NP, Lindhe J. Spontaneous progression of ligature induced peri-implantitis at implants with different surface roughness: an experimental study in dogs. Clin Oral Implants Res 2007; 18:655–661.
21. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (II). Etiopathogenesis. Eur J Oral Sci 1998; 106:721–764.
22. Donos N, Mardas N, Chadha V. Clinical outcomes of implants following lateral bone augmentation: systematic assessment of available options (barrier membranes, bone grafts, split osteotomy). J Clin Periodontol 2008; 35: 173–202.
23. Tan WC, Lang NP, Zwahlen M, Pjetursson BE. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: transalveolar technique. J Clin Periodontol 2008; 35:241–254.
24. Aglietta M, Siciliano VI, Zwahlen M, et al. A systematic review of the survival and complication rates of implant supported fixed dental prostheses with cantilever extensions after an observation period of at least 5 years. Clin Oral Implants Res 2009; 20:441–451.
25. Pjetursson BE, Lang NP. Prosthetic treatment planning on the basis of scientific evidence. J Oral Rehabil 2008; 35 (Suppl 1):72–79.
26. Mertens C, Steveling HG. Implant-supported fixed prostheses in the edentulous maxilla: 8-year prospective results. Clin Oral Implants Res 2011; 22:464–472.
27. Mombelli A, van Oosten MA, Schurch E Jr, Land NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol 1987; 2:145–151.
28. Lang NP, Tonetti MS. Periodontal risk assessment (PRA) for patients in supportive periodontal therapy (SPT). Oral Health Prev Dent 2003; 1:7–16.
29. Kornman KS, Crane A, Wang HY, et al. The interleukin-1 genotype as a severity factor in adult periodontal disease. J Clin Periodontol 1997; 24:72–77.
30. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants 1986; 1:11–25.
31. Karoussis IK, Salvi GE, Heitz-Mayfield LJ, Bragger U, Hammerle CH, 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 Implants Res 2003; 14:329–339.
32. Buser D, Weber HP, Lang NP. Tissue integration of non-submerged implants. 1-year results of a prospective study with 100 ITI hollow-cylinder and hollow-screw implants. Clin Oral Implants Res 1990; 1:33–40.
33. Bragger U, Aeschlimann S, Burgin W, Hammerle CH, Lang NP. Biological and technical complications and failures with

fixed partial dentures (FPD) on implants and teeth after four to five years of function. Clin Oral Implants Res 2001; 12:26–34.

34. Mombelli A, Lang NP. Clinical parameters for the evaluation of dental implants. Periodontol 2000 1994; 4:81–86.
35. Albrektsson Z, Isidor F. Consensus report of session IV. London: Quintessence Publishing Co. Ltd, 1994.
36. Kaplan E, Meier P. Nonparametric estimation from incomplete observations. J Am Stat Assoc 1958; 53:457–481.
37. Al-Nawas B, Kammerer PW, Morbach T, Ladwein C, Wegener J, Wagner W. Ten-year retrospective follow-up study of the TiOblast dental implant. Clin Implant Dent Relat Res 2010. DOI 10.1111/j.1708-8208.2009.00237.x. [Epub ahead of print].
38. Gotfredsen K. A 10-year prospective study of single tooth implants placed in the anterior maxilla. Clin Implant Dent Relat Res 2009. DOI: 10.1111/j.1708-8208.2009.00231.x. [Epub ahead of print].
39. Jacobs R, Pittayapat P, van Steenberghe D, et al. A split-mouth comparative study up to 16 years of two screw-shaped titanium implant systems. J Clin Periodontol 2010; 37:1119–1127.
40. Vroom MG, Sipos P, de Lange GL, et al. Effect of surface topography of screw-shaped titanium implants in humans on clinical and radiographic parameters: a 12-year prospective study. Clin Oral Implants Res 2009; 20:1231–1239.
41. Jemt T, Stenport V. Implant treatment with fixed prostheses in the edentulous maxilla. Part 2: prosthetic technique and clinical maintenance in two patient cohorts restored between 1986 and 1987 and 15 years later. Int J Prosthodont 2011; 24:356–362.
42. Jemt T, Stenport V, Friberg B. Implant treatment with fixed prostheses in the edentulous maxilla. Part 1: implants and biologic response in two patient cohorts restored between 1986 and 1987 and 15 years later. Int J Prosthodont 2011; 24:345–355.
43. Hardt CR, Grondahl K, Lekholm U, Wennstrom JL. Outcome of implant therapy in relation to experienced loss of periodontal bone support: a retrospective 5- year study. Clin Oral Implants Res 2002; 13:488–494.
44. Mengel R, Behle M, Flores-de-Jacoby L. Osseointegrated implants in subjects treated for generalized aggressive periodontitis: 10-year results of a prospective, long-term cohort study. J Periodontol 2007; 78:2229–2237.
45. Armitage GC. Development of a classification system for periodontal diseases and conditions. Ann Periodontol 1999; 4:1–6.
46. Haas R, Haimbock W, Mailath G, Watzek G. The relationship of smoking on peri-implant tissue: a retrospective study. J Prosthet Dent 1996; 76:592–596.
47. Persson GR, Samuelsson E, Lindahl C, Renvert S. Mechanical non-surgical treatment of peri-implantitis: a single-blinded randomized longitudinal clinical study. II. Microbiological results. J Clin Periodontol 2010; 37:563–573.
48. Jemt T. Fixed implant-supported prostheses in the edentulous maxilla. A five-year follow-up report. Clin Oral Implants Res 1994; 5:142–147.