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5-year clinical experience with BTI® dental implants: risk factors for implant failure

Eduardo Anitua[1,2], Gorka Orive[2], José Javier Aguirre[2], Bruno Ardanza[3] and Isabel Andía[2]

[1]Private Practice in Implantology and Oral Rehabilitation, Vitoria, Spain; [2]Biotechnology Institute I MAS D, Vitoria, Spain; [3]Private practice in Oral Rehabilitation, Logroño, Spain

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Abstract

Objectives: The aims of this study were to identify with appropriate statistical tests the risk factors associated with implant failure and to evaluate the long-term survival of dental implants using implant loss as an outcome variable and performing an implant-, surgery- and patient-based analysis of failures.

Material and Methods: A retrospective cohort study design was used. One thousand sixty patients received 5787 BTI® implants during the years of 2001–2005 in Vitoria, Spain. The potential influence of demographic items, clinical items, surgery-dependent items and prosthetic variables on implant survival was studied. Implant survival was analysed using a life-table analysis. Cox proportional hazards regression was used to identify risk factors related to implant failure.

Results: Smoking habits, implant position, implant staging (two-stage implants) and the implementation of special techniques were statistically correlated with lower implant survival rates. Two risk factors associated with implant failure were detected in this study: implant staging (two-stage implants) and the use of special techniques. Additionally, the overall survival rates of BTI® implants were 99.2%, 96.4% and 96% for the implant-, surgery- and patient-based analysis, respectively. Totally, 28 out from 5787 implants (0.48%) were lost during the observation period. Most of the patients with implant failure (69.6%) presented chronic or aggressive periodontitis.

Conclusions: Implant staging and the use of special techniques are risk factors for implant failure.

Key words: Cox regression analysis; dental implants; follow-up analysis; PRGF; risk factors; survival analysis

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In the last few decades, the field of dental implantology is advancing significantly, leading to more predictable treatments for the rehabilitation of fully and partially edentulous patients. Correct design of implant surface, faster osseointegration of the implants, extensive understanding of the biomechanical properties of the implants and selection of the suitable surgical technique according to a patient's bone quantity and quality are major parameters affecting the long-term survival and success of dental implants.

A large number of longitudinal studies have evaluated the prognosis and long-term functionality of the different dental implants, reporting survival rates of around 90–96% over periods of 5–10 years (Esposito et al. 1998, Berglundh et al. 2002, Roos-Jansåker et al. 2006a). However, many studies describe simple implant survival in favourable locations without assuming factors that could be adverse to implant survival. Furthermore, most reports evaluating risk factors for failure are flawed in terms of their statistical analyses. To address these issues and properly evaluate the long-term result of implant therapy, a large number of implants installed in different anatomical positions and after different surgical procedures should be considered. In addition, the potential risk factors for failure should be carefully determined using powerful and suitable statistical techniques.

In the present study, we report the results of a 5-year clinical experience with respect to the efficacy of 5787 Biotechnology Institute (BTI®) dental

Conflict of interest and sources of funding statement

This study was financially supported by Biotechnology Institute (BTI), the manufacturer of the implant system used in this study. Dr. Orive, Dr. Andía and José Javier Aguirre are employed by BTI. Dr. Anitua is scientific director of BTI.

implants. We believe this is one of the studies with the largest number of dental implants under evaluation. The implants under study present a micro-rough acid-etched surface and a great cutting capacity due to their apex design. These implants constitute the first bioactive surface on the market (Anitua 2006) as a preparation rich in growth factors (PRGF), a limited volume of plasma enriched in platelets, is used to humidify the implant surface and thus create an autologous protein layer that will accelerate and improve implant osseointegration (Anitua et al. 2004, 2006a). The principal aim of this retrospective work is to identify potential risk factors related to implant failure-using a failure-time multivariate model. Additionally, the long-term survival of 5787 implants was evaluated. To address this issue, an implant-, surgery- and patient-based analysis of failures has been carried out with the aim of providing more complete, comprehensive and comparable data. A better understanding of the factors associated with implant failure will provide data for improving clinical decision-making and thus enhance implant long-term success.

Material and Methods

The protocol followed national and international (ICH rules) policies on clinical studies. Patient selection was based on the absence of any local or systemic diseases that might contraindicate the treatment. The study reports on patients treated with BTI® implants (Biotechnology Institute, Vitoria, Spain) from January 2001 to December 2005. During this period, 1060 consecutive patients were provided with at least one dental implant for a total number of 5787 implants. No loss to follow-up was observed during this retrospective study. Before implant installation, dentate patients were, if needed, periodontally treated to obtain periodontal health.

Antibiotics were prescribed to each patient for 6 days, starting 30 min. before implant installation. Anti-inflammatory and analgesic drugs were also administered 30 min. preoperatively. Saline solution rinses (during 48 h) and additional twice-daily chlorhexidine (0.12% w/v) rinses were recommended until sutures were removed. The latter was mainly used in patients with a poor oral hygienic situation. Patients were instructed on how to maintain proper oral hygiene around implants.

The clinical histories of all patients were carefully evaluated and the surgical procedures were chosen as a function of the patient characteristics, the anatomic peculiarities of the insertion sites and intrinsic properties of the different BTI® implants. All implant installations were performed by two experienced surgeons following an adequate treatment plan and rehabilitations were carried out by three prosthodontists. The latter included careful evaluation of the patient's clinical history, a complete radiological evaluation (conventional X ray and the BTI Scan® program), the elaboration of surgery guides and the preparation of provisional and final prostheses adapted to each patient.

All implants were installed without irrigation using a low-speed drilling procedure (50 r.p.m.) (Anitua et al. 2007). Before installation, all implants were carefully embedded in liquid PRGF with the aim of bioactivating the implant surface (Anitua et al. 2004, 2006, 2006a). PRGF was prepared from the patient's citrated blood, by centrifugation at $460 \times g$ for 8 min. at room temperature, and the 0.5 ml fraction just located above the sedimented red cells, but not including the buffy coat, was collected (Anitua et al. 2007). Immediately loaded implants were installed only when bone densitometry determined by means of the BTI Scan® program was $\geqslant$500 Hounsfield units and the insertion torque measured by a dynamometric ratchet wrench ranged between 45 and 65 Ncm. In these cases, the suprastructure was placed within approximately 24 h. In general, in the rest of the cases healing was allowed for a minimum of 3 months, after which the surgical abutments were fitted. Shortly thereafter, the suprastructure was placed. Maxillary sinus elevation was performed by an ultrasonic ostectomy approach as described elsewhere (Torrella et al. 1998) using a mixture of BioOss® with PRGF as the graft material. In the case of crest expansion, autologous bone obtained from a low-speed drilling procedure (Anitua et al. 2007) mixed with PRGF was used as graft material and, in a few cases, demineralized human bone mixed with PRGF was used.

Between January 2001 and December 2005, the patients were called in for oral hygiene and clinical and radiographic examinations at least twice a year. At the end of the study, periodontal disease status of the failing cases was evaluated following the classification of periodontal disease provided by Armitage (1999). According to this, periodontal diseases are classified on the basis of extent and severity. Extent can be characterized as localized ($\leqslant$30% sites involved) and generalized ($\geqslant$30% sites involved). Severity can be defined on the basis of the amount of clinical attachment loss (CAL), being: slight (1–2 mm CAL,) moderate (3–4 mm CAL) and severe ($\geqslant$5 mm CAL).

Several items were used for data analysis in the present report. These variables include demographic items, clinical items, surgery-dependent items and prosthetic variables:

- Age at initial examination (categorized into three categories: $<$45 years, 45–64 years and $>$65 years).
- Smoking habits (smoking $\geqslant$1 cigarette per day was classified as a smoker).
- Implant position (maxillary; mandibulary; anterior = incisor/cuspid region; posterior = premolar/molar region).
- Implant diameter (ranging from 2.5 to 5.5 mm). Implant diameter was divided into four categories: $<$3.3, 3.3, 3.75–4 and 4.5–5 mm.
- Implant length (ranging from 7.5 to 18 mm). Implant length was divided into two categories: $<$10 and $\geqslant$10 mm.
- Implant staging (one-stage *versus* two-stage implants).
- Special techniques (immediately loaded implants, sinus elevation and crest expansion). This item was divided into two categories depending on the use or not of the special techniques.
- Prosthetic items: divided into cemented bridge, cemented unitary and hybrid overdenture.

Statistical analyses

Data collection and analysis was performed by two independent examiners (other than restorative dentists). Descriptive statistics were performed and absolute and relative frequency distributions for qualitative variables and mean values and standard deviations for quantitative variables were calculated. Initially, a database was created using Microsoft Access®. The principal variable under study was implant loss. Implant loss was considered any implant lost due to biological (failure to achieve osseointegration or loss of acquired osseointegration) or biomechanical causes. From a temporal point of view, implant loss was classified into early implant loss (before functional loading) or late implant loss (following functional loading). The rest of the variables for data analysis of this report included the previously cited demographic items, clinical items, surgery-dependent items and prosthetic variables.

The overall survival rate of BTI® implants was estimated by an implant-, surgery- and patient-based analysis. In the implant-based analysis, each inserted implant was considered as the analysis unit whereas in the surgery-based analysis each patient was considered the analysis unit as many times as the number of implant surgical sessions undertaken. Assuming the latter, the final number of patients increased to 1253. Finally, in the patient-based analysis each patient was considered only one time independently of the number of implants received.

In all types of analysis, implant survival as a function of time was analysed using a life-table analysis (actuarial method), comparing the survival rates among the different variables with the Wilcoxon test (Gehan). Cox proportional hazards regression (forward stepwise selection: -2 log likelihood ratio test) was used to identify the risk factors related to implant failure. The covariates under study include gender, age, smoking habits, implant length and diameter, implant position, implant staging, immediate *versus* delayed loading and the necessity for special techniques.

Data analysis was performed with SPSS 13 for Windows statistical software package (SPSS Inc., Chicago, IL, USA). The level of statistical significance was $p<0.05$.

Table 1. Characteristics of the inserted BTI® implants

		Diameter (mm)								Total
		2.50	3.00	3.30	3.75	4.00	4.50	5.00	5.50	
Longitude (mm)	7.5	–	–	–	36	20	61	27	2	146
	8.5	–	–	46	135	110	159	95	6	551
	10.0	6	7	105	262	190	342	195	10	1117
	11.5	10	6	86	221	168	246	123	4	864
	13.0	14	27	222	541	384	264	146	4	1602
	15.0	8	29	321	440	413	148	92	3	1454
	18.0	–	–	24	19	10	–	–	–	53
Total	38	38	69	804	1654	1295	1220	678	29	5787

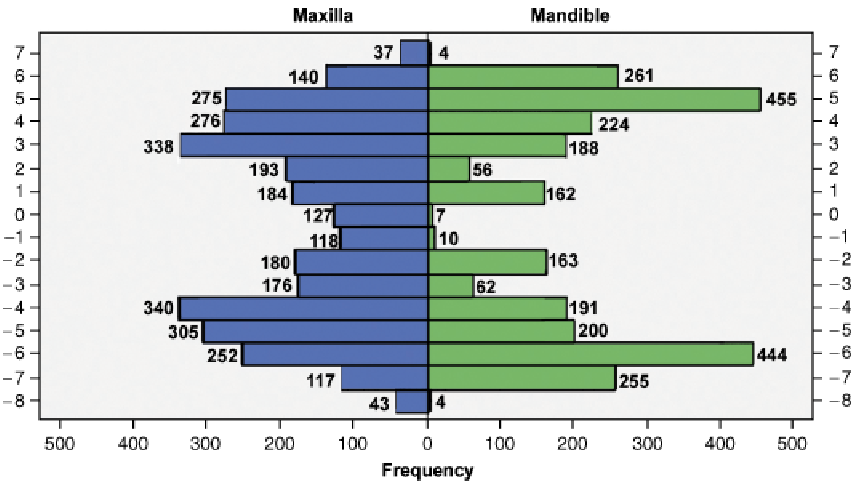

Fig. 1. Anatomic distribution of the 5787 BTI® implants.

Results

A total of 1060 clinical histories were revised during this study. At the beginning of the study the mean age of the 1060 patients was 54 years (range 17–91 years). Six hundred and seventy four patients were female (63.6%). Two hundred twenty one patients were classified as smokers (20.9%). A total of 5787 dental implants were inserted. The specific characteristics of the inserted implants (length and diameter) are summarized in Table 1. One hundred seventy five patients (16.5%) received only one implant, 175 patients (16.5%) received two implants, 114 patients (10.8%) received three implants and 596 patients (56.2%) received four or more implants. Attending to the number of surgeries, 882 patients (83.2%) undertook one single surgical procedure, 164 patients (15.5%) had two surgical procedures, 13 patients (1.2%) had three surgical procedures and one patient undertook four.

Regarding implant position, 3101 were inserted in to the upper (53.6%) and 2686 in to the lower jaw. A total of 4349 implants were installed in posterior areas (75.2%). Figure 1 summarizes the distribution of the 5787 dental implants.

Considering the surgical approach, 4458 implants were installed using a one-stage surgery (77%) and 1329 implants followed a two-stage surgery approach. One thousand two hundred and seventy-three implants (25.3%) were installed following special techniques: 207 implants followed an immediate post-extraction approach, graft techniques were used in 1046 implants, 175 implants were inserted after crest expansion and 34 implants after maxillary sinus elevation. On the other hand, 4109 implants (71%) supported cemented bridges, 1042 complete prostheses (18%) and 579 unitary cemented prostheses (10%). Use of screw-retained permanent prostheses was residual (0.07%).

Table 2 presents the length of observation time of the studied group by patient, by surgery and by implant. The total number of patients in the surgical-based analysis was increased to 1253 as each patient was considered the analysis unit as many times as the number of implant surgical sessions was undertaken. 56.2% of the patients and 55% of the implants had a follow-up of more than 24 months. The mean follow-up period for all implants was 28.63 ± 15.2 months, ranging from 2 to 59 months. In the case of the surgery-based analysis, the mean follow-up was 29.15 ± 15.8 months, ranging from

Table 2. Months of follow-up by patient, surgery and implant

Months of follow-up	Implants		Surgery		Patients	
	frequency	%	frequency	%	frequency	%
< 12	1040	18.0	246	19.6	186	17.5
12–24	1577	27.3	304	24.3	242	22.8
24–36	1327	22.9	279	22.3	238	22.5
36–48	1052	18.2	229	18.3	200	18.9
48–60	791	13.7	195	15.6	194	18.3
Total	5787	100	1253	100.0	1060	100.0

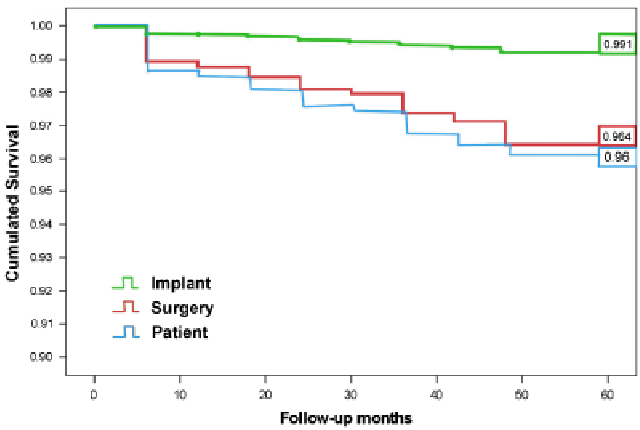

Fig. 2. Implant survival rates for the implant, surgery and patient-based analysis.

2 to 59 months, whereas in the case of patients, the mean follow-up was 30.45 ± 15.9 months, ranging from 2 to 59 months.

Implant survival and implant loss

The overall survival rate of dental implants was estimated by an implant-, surgery- and patient-based analysis. At the end of the study period, the survival rates using the actuarial method were 99.2%, 96.4% and 96% for the implant-, surgery- and patient-based analysis, respectively (Fig. 2).

Totally, 28 of the 5787 implants (0.48%) were lost during the observation period. Each case has been carefully analysed in order to properly understand the causes of implant loss. Fifteen implants in 15 patients were lost within the first year of loading. An additional 13 implants in 10 patients were lost later. Fifteen implant losses correspond to a one-stage surgery. A complete description of the reasons for each implant loss is summarized in Table 3. Interestingly, the evaluation of the periodontal disease status of the failing cases revealed that 16 of these 23 patients (69.6%) presented chronic or aggressive periodontitis (the remaining five patients were edentulous). Briefly, eight patients presented generalized and severe chronic periodontitis, four had generalized and moderate chronic periodontitis and the remaining four presented localized aggressive periodontitis.

We investigated the potential influence of the different variables on implant survival. After comparing the survival rates among the different variables with the Wilcoxon test, statistical significance was observed for the following items: smoking habits, implant position, implant staging (two-stage implants) and the implementation of special techniques (Table 4). Briefly, smoking was correlated with a lower implant survival rate ($p<0.013$) both for the implant-based and for the patient-based analysis. The rest of the items were correlated with lower viability rates only in the implant-based analysis. In fact, implants inserted in to the maxilla and those implanted with a two-stage surgery showed lower implant survival rates ($p<0.031$ and $p<0.008$, respectively). Finally, the necessity for special techniques also resulted in lower survival rates ($p<0.033$).

The multivariate Cox regression analysis of the different variables revealed that when the implant was considered as the analysis unit, only the use of special techniques and the implant staging (two-stage implants) had a significant influence on implant failure with respect to the 10 events considered. In fact, the risk for implant failure is 2.28 times more likely in two-stage implants than one-stage implants ($p<0.035$, 95% CI = 1.06–4.90) whereas the risk for implant failure is 2.5 times higher when special techniques are used ($p<0.04$, 95% CI = 0.18–0.85). Figures 3 and 4 describe the implant survival rates using the Cox proportional hazards regression evaluating the use of special techniques (Fig. 3) and implant staging (two-stage *versus* one-stage implants) (Fig. 4). Finally, Fig. 5 illustrates the clinical situation of one patient involved in the study before and 5 years after implant placement. The excellent implant osseointegration 5 years post-surgery and soft tissue integration of the final prosthetic work are clearly shown.

Discussion

The patients included in the present retrospective study were treated with dental implants by two experienced clinicians in oral surgery and dental implantology. All implants were installed following BTI® general guidelines for implant insertion, using a low-speed drilling procedure and without irrigation (Anitua et al. 2006b). In addition, all implants were humidified with PRGF in order to bioactivate their surfaces by creating a protein layer that stimulated the mechanism of bone formation at the implant–bone interface and promoted faster implant osseointegration (Anitua et al. 2004, 2006). Surgical procedures and patient's follow-up were similar for all individuals. Furthermore, because all patients were treated with the same implants, the potential differences between implants systems were disregarded.

The long-term efficacy and prognosis of dental implants is usually measured by the survival rates. One outstanding consideration when studying the survival rate of a specific dental implant is to evaluate a large number of implants installed following different surgical approaches and in different bone quality and quantity locations. This should provide more objective and real information on the efficacy and biosafety of the implants. Some studies include only a

Table 3. Description of implant failures and the main reasons detected for each implant loss

Patient			Implant		Surgery			Implant loss	
age	gender	smoking habits	length (mm)	diameter (mm)	localization	implant staging	special techniques	causes	follow-up (months)
57	Male	Yes	15.0	5.00	13	2 stage	Yes	Bruxist Immediate load Overload in bone class III	2
71	Female	No	10.0	2.50	11	1 stage	No	Crest expansion in extremely reabsorbed crest	3
38	Female	Yes	10.0	3.30	21	2 stage	Yes	Heavy smoker Narrow crest	3
45	Female	Yes	15.0	3.30	42	1 stage	Yes	Immediate load in post-extraction site	3
60	Female	Yes	10.0	4.50	35	1 stage	No	Short implant pushed out by tongue	3
55	Male	No	13.0	4.00	14	1 stage	No	Bruxist Bone class IV	4
70	Male	No	10.0	3.75	17	1 stage	No	Bone class IV	4
49	Female	No	11.5	3.30	34	2 stage	No	Extreme expansion	4
45	Male	Yes	11.5	3.30	24	1 stage	No	Immediate load Bone class III	4
57	Female	Yes	8.5	4.00	16	2 stage	No	Bone class IV	4
48	Female	Yes	8.5	3.75	13	2 stage	No	Very narrow crest	5
55	Female	No	15.0	4.00	18	2 stage	No	Pterigoides	5
70	Female	No	10.0	3.75	14	1 stage	No	Immediate load in bone class III	5
60	Female	No	8.5	3.75	12	2 stage	No	Nasal floor lift	7
43	Female	Yes	10.0	5.00	47	1 stage	No	Bone class IV	10
53	Female	No	15.0	3.30	14	1 stage	Yes	Bone class IV	12
40	Female	Yes	13.0	4.00	27	2 stage	Yes	Tuberosity bone class IV	12
58	Female	No	10.0	3.30	11	2 stage	Yes	Extreme expansion	12
61	Male	Yes	15.0	5.50	44	1 stage	Yes	Immediate load Bruxist	18
48	Male	No	18.0	3.30	22	1 stage	Yes	Narrow crest Post-extraction implantation without flap elevation	20
54	Male	Yes	13.0	4.00	16	2 stage	Yes	Sinus lift by compression	21
53	Male	No	11.5	4.50	46	1 stage	No	Severe bone loss because of compression	25
45	Female	No	11.5	3.30	24	1 stage	No	Immediate load after narrow crest expansion	32
47	Male	Yes	13.0	3.75	14	1 stage	Yes	Bone class III	34
48	Male	No	11.5	3.75	15	1 stage	Yes	Bruxist suffering depression	35
48	Male	No	13.0	3.75	24	2 stage	Yes	Bruxist suffering depression	45
48	Male	No	11.5	3.75	25	2 stage	Yes	Bruxist suffering depression	40
42	Female	No	8.5	3.75	45	2 stage	No	Fracture because of cantilever overload	38

reduced number of implants and patients whereas others describe simple implant survival in favourable locations without assuming factors that could be adverse to implant survival. Additionally, many studies present inefficient statistical analyses of the data that might lead to the assumption of incorrect conclusions.

Here, we have studied the survival rate of 5787 dental implants installed in more than 1000 patients. The survival rate of dental implants has been estimated by an implant-, surgery- and patient-based analysis in order to provide a more complete, comprehensive and comparable data analysis. Our principal aim has been to identify potential risk factors associated with implant loss in a statistically appropriate and valid manner. This is, to our knowledge, one of the studies with the largest number of dental implants under evaluation. The implants were placed following different surgical approaches (one-stage and two-stage surgeries, immediately post-extraction, sinus elevation and crest expansion) in different anatomical positions and using different types of prostheses.

The implants under study in this retrospective study are characterized by a great cutting capacity because of their apex design and by a micro-rough acid-etched surface that facilitates implant insertion, minimizing compression and host bone damage. A rough acid-etched surface has shown significantly greater bone-to-implant contact when compared with machined or polished surfaces (Buser et al. 1991, Wennerberg et al. 1995, Vörös et al. 2001). Furthermore, by humidifying implant surfaces with PRGF it is possible to improve the biological properties of the implants (Anitua et al. 2004).

The primary outcome variables, that is the survival rates of the implants using the actuarial method, were 99.2%, 96.4% and 96% for the implant-, surgery- and patient-based analyses, respectively. These results improve the typical survival estimates reported in the literature, which range from 90% to 98% (Behneke et al. 2000,

Table 4. Univariate analysis of implant survival using a life-table analysis, comparing the survival rates among the different variables with the Wilcoxon test (total patients = 1060 patients; total implants n = 5787)

		n	Median survival time (months)	Cumulative proportion surviving at end of interval	SE	Statistical comparison among groups (Wilcoxon–Gehan)
Patient	Male	2105	54	0.987	0.002	NS
	Female	3682	54	0.994	0.005	
	<45 years	773	54	0.992	0.004	NS
	45–64 years	4045	54	0.991	0.002	
	>64 years	969	54	0.991	0.002	
	Non Smokers	4488	54	0.993	0.002	$p = 0.013$
	Smokers	1299	54	0.989	0.003	
Diameter	<3.3 mm	107	18	0.990	0.010	NS
	3.3 mm	804	54	0.988	0.004	
	3.75–4 mm	2949	54	0.992	0.002	
	4.5–5 mm	1927	48	0.996	0.002	
Length	⩾10 mm	5090	54	0.992	0.002	NS
	<10 mm	697	54	0.990	0.006	
Localization	Maxilla	3101	54	0.989	0.003	$p = 0.031$
	Mandible	2686	54	0.996	0.002	
	Anterior	4349	54	0.994	0.002	NS
	Posterior	1438	54	0.991	0.002	
Stages	One stage	4458	54	0.995	0.001	$p = 0.008$
	Two stage	1329	54	0.983	0.006	
Special techniques	Non	4529	54	0.995	0.001	$p = 0.033$
	Yes	1258	54	0.981	0.006	
Prosthetic items	Cemented bridge	4115	54	0.992	0.003	NS
	Hybrid-Overdenture	1046	54	0.990	0.004	
	Cemented unitary	593	54	0.993	0.004	
Global		5787	54	0.992	0.002	

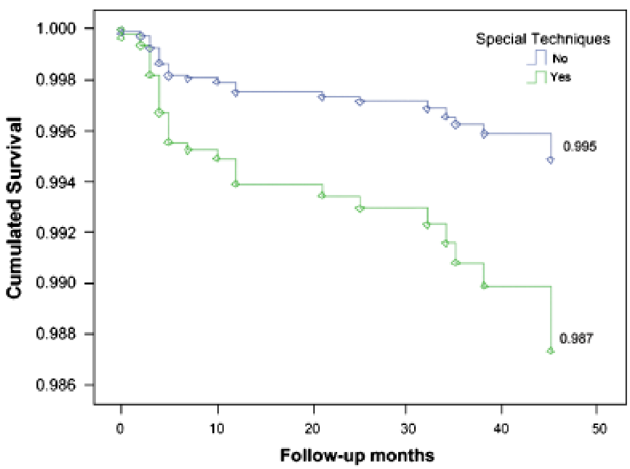

Fig. 3. Survival estimates using Cox proportional hazards regression attending to the necessity of special techniques.

Weibrich et al. 2001, Leonhardt et al. 2002). In a recent article revising 59 references of six implant manufacturers, a 5-year implant survival rate of 96% (CI: 93–98%) was demonstrated (Eckert et al. 2005).

In our study only 28 implants were lost during the observation period, leading to an overall failure rate of 0.48%. Most of these implant losses were concentrated in a small number of individuals. In fact, three out of 28 implant losses (10%) occurred in the same individual, a bruxism patient under anti-depression medication. We have carefully analysed each implant loss in order to determine the exact reasons that most likely led to the loss of the implants. Interestingly, most of the patients (70.8%) with implant failure presented a moderate or advanced periodontitis. Periodontitis patients may be exposed to a higher risk for peri-implantitis, which in turn may lead to implant loss (Roos-Jansåker et al. 2006b). Baelum & Ellegaard (2004) reported 78% 10-year survival rates for implants placed in periodontitis patients, indicating that the prognosis might be less favourable in patients with a history of periodontitis. In a more recent article, the risk variables associated with peri-implantitis were analysed in 212 partially edentulous subjects rehabilitated with osseointegrated implants. Results show that subjects with periodontitis, diabetes and poor oral hygiene were more prone to developing peri-implantitis (Ferreira et al. 2006).

Although it is not possible from the data presented herein to definitely ascribe implant loss to the periodontal disease status of the patients, it is possible that the latter may at least in part contribute to some of the implant failures detected in this study. To address this issue properly, we will analyse, follow and collect the periodontal disease status of all patients involved in future prospective studies.

Regarding the potential risk factors, although a significant relationship between smoking habits and implant loss was not observed in this study, the

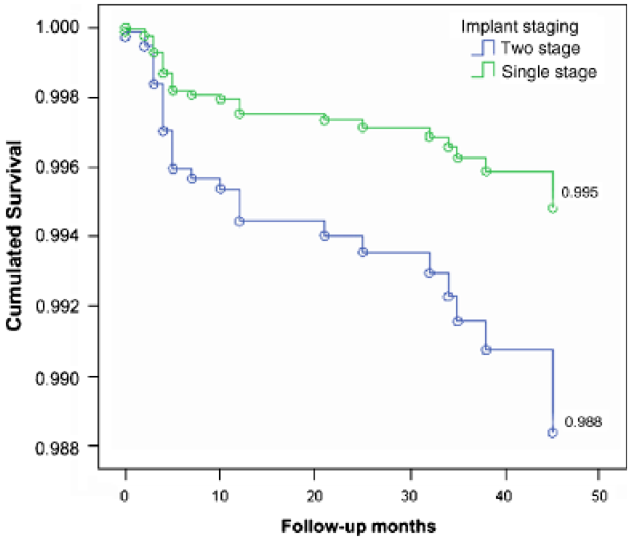

Fig. 4. Survival estimates using Cox proportional hazards regression attending to implant staging (one-stage *versus* two-stage implants)

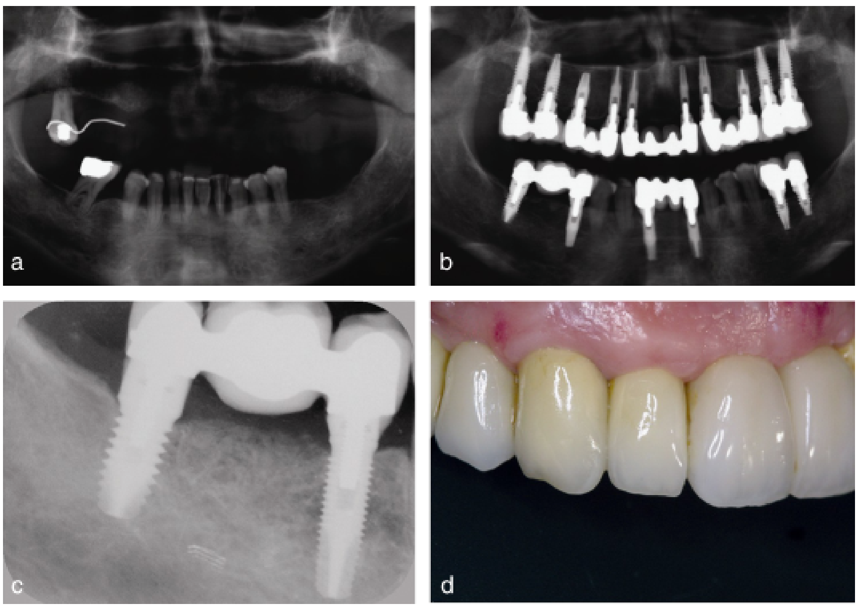

Fig. 5. Example of one case involved in the study. (a) Radiograph before surgery; (b) Radiograph after implant placement; (c) Implant osseointegration 5 years post-surgery; (d) Perfect esthetic integration of the definitive prosthesis.

comparison of the survival rates among the different variables demonstrated that smoking reduces the implant survival rate. Many studies have reported a deleterious effect of smoking on implant survival (Wilson & Nunn 1999, Hinode et al. 2006). Recently, a systematic literature review was performed to investigate whether smoking interferes with the prognosis of dental implants. The results from this systematic review indicated significantly enhanced risks of biological complications among smokers and considered smoking as a significant risk factor for dental implant therapy (Strietzel et al. 2007). The lack of statistical significance for smoking in this study may be related to the small number of individuals with implant loss, thereby reducing the power of the statistical analysis.

A similar behaviour has been observed for implant position (upper *versus* lower jaw). Upper jaw implant insertion was not found to be a risk factor for implant loss. However, the survival estimates were significantly lower than those for implants placed in the mandible. These results might be a consequence of the overall less favourable osseous situation in patients demanding a maxillary reconstruction. In fact, the number of implants inserted according to a two-stage protocol (1139 in the upper *versus* 190 in the lower jaws, $p<0.001$) and special techniques (904 in the upper *versus* 354 in the lower jaws, $p<0.001$) performed in the maxilla were significantly higher than in the mandible. In a recent study evaluating 4680 implants in 1140 patients, implants placed in the maxilla experienced almost twice the failure rate of those inserted into the mandible (Moy et al. 2005). Other studies have also shown these results, suggesting a higher failure for implants inserted into the maxilla (Eckert & Wollan 1998, Davarpanah et al. 2002).

The only two factors that showed significant association with implant loss in the multivariate Cox model and thus were considered risk factors for implant failure were the use of special techniques and implant staging (two-stage implants). The latter is a controversial concept as some authors report no differences between one-stage *versus* two-stage implants (Baelum & Ellegaard, 2004) while others indicate that one-stage implants have a lower survival rate than two-stage implant systems (Vehemente et al. 2002). The fact that patients following one-stage implant showed better results may reflect good treatment planning for the reason that more complicated treatments would preferentially be performed in two stages. In line with our results, a recent study identified implant staging (two-stage implants) as a risk factor significantly associated with implant failure (Chuang et al. 2002).

Retrospective studies rely on the completeness of data entered in the patient's chart. This may implicate the risk of missing data because of misplaced, misfiled or missing information in the chart. There is no reason, however, to believe that any of these records were selectively missing due to the presence or absence of any key variable. On the other hand, despite the robust statistical analysis for failure time data, the incomplete recording of some confounding risk factors such as periodontal disease status for all the patients may hamper a more complete interpretation of the results. This should be kept in mind when interpreting the results.

In summary, the principal outcome of this retrospective study is that we have demonstrated that the survival rates of 5787 BTI® implants were 99.2%, 96.4% and 96% assuming a patient-, surgery- and implant-based analysis, respectively. These data indicate that treatment with BTI® implants is safe and predictable, which, in our opinion, may help to improve decision-making of clinicians. The 28 implants lost during the observation period (0.48%) have been carefully studied and the main reasons for those implant failures have been determined. Another key finding is that we have identified two risk factors associated with implant failure: implant staging (two-stage implants) and the necessity for special techniques. It is also important to remark that this is a retrospective study on implant survival and therefore other clinical parameters will need to be considered to appreciate a long-term clinical success. However, although this retrospective study has less validity than randomized prospective clinical trials, especially due to issues of selection bias and confounding, the information provided in this study might help clinicians to improve their decision-making and thus enhance implant success.

References

Anitua, E. (2006) Enhancement of osseointegration by generating a dynamic implant surface. *Journal of Oral Implantology* **32**, 72–76.

Anitua, E., Andia, I., Ardanza, B., Nurden, P. & Nudern, A. T. (2004) Autologous platelets as a source of proteins for healing and tissue regeneration. *Thrombosis Haemostasis* **91**, 4–15.

Anitua, E., Carda, C. & Andia, I. (2007) A novel drilling procedure and subsequent bone autograft preparation: a technical note. *International Journal of Oral and Maxillofacial Implants* **22**, 138–145.

Anitua, E., Sánchez, M., Nurden, A. T., Nurden, P., Orive, G. & Andía, I. (2006a) New insights into and novel applications for platelet-rich fibrin therapies. *Trends in Biotechnology* **24**, 227–234.

Anitua, E., Sánchez, M., Nurden, A. T., Zalduendo, M., de la Fuente, M., Orive, G., Azofra, J. & Andía, I. (2006b) Autologous fibrin matrices: a potential source of biological mediators that modulate tendon cell activities. *Journal Biomedical Materials Research* **77**, 283–295.

Armitage, G. C. (1999) Development of a classification system for periodontal diseases and conditions. *Annals of Periodontology* **4**, 1–6.

Baelum, V. & Ellegaard, B. (2004) Implant survival in periodontally compromised patients. *Journal of Periodontology* **75**, 1404–1412.

Behneke, A., Behneke, N. & d'Hoedt, B. (2000) The longitudinal clinical effectiveness of ITI solid-screw implants in partially edentulous patients: a 5-year follow up report. *International Journal of Oral and Maxillofacial Implants* **15**, 633–645.

Berglundh, T., Persson, L. & Klinge, B. (2002) A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *Journal of Clinical Periodontology* **29**, 197–212.

Buser, D., Schenk, R. K., Steinemann, S., Fiorellini, J., Fox, C. & Stich, H. (1991) Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. *Journal Biomedical Materials Research* **25**, 889–902.

Chuang, S. K., Wei, L. J., Douglass, C. W. & Dodson, T. B. (2002) Risk factors for dental implant failure: a strategy for the analysis of clustered failure-time observations. *Journal of Dental Research* **81**, 572–577.

Davarpanah, M., Martínez, H., Etienne, D., Zabalegui, I., Mattout, P., Chiche, F. & Michel, J. F. (2002) A prospective multicenter evaluation of 1583 3i implants: 1–5 year data. *International Journal of Oral and Maxillofacial Implants* **17**, 820–828.

Eckert, S. E., Choi, Y. G., Sánchez, A. R. & Koka, S. (2005) Comparison of dental implant systems: quality of clinical evidence and prediction of 5-year survival. *International Journal of Oral and Maxillofacial Implants* **20**, 406–415.

Eckert, S. E. & Wollan, P. C. (1998) Retrospective review of 1170 endosseus implants placed in partially edentulous jaws. *Journal of Prosthetic Dentistry* **79**, 415–421.

Esposito, M., Hirsch, J. M., Lekholm, U. & Thomsen, P. (1998) Biological factors contributing to failures of osseointegrated oral implants (I). Success criteria and epidemiology. *European Journal of Oral Sciences* **106**, 527–551.

Ferreira, S. D., Silva, G. L. M., Cortelli, J. R., Costa, J. E. & Costa, F. O. (2006) Prevalence and risk variables for peri-implant disease in Brazilian subjects. *Journal of Clinical Periodontology* **33**, 929–935.

Hinode, D., Tanabe, S., Yokoyama, M., Fujisawa, K., Yamauchi, E. & Miyamoto, Y. (2006) Influence of smoking on osseointegrated implant failure: a meta-analysis. *Clinical Oral Implants Research* **17**, 473–478.

Leonhardt, A., Grondahl, K., Bergstrom, C. & Lekholm, U. (2002) Long-term follow-up of osseointegrated titanium implants using clinical, radiographic and microbiological parameters. *Clinical Oral Implants Research* **13**, 127–132.

Moy, P. K., Medina, D., Shetty, V., Dent, M. & Aghaloo, T. L. (2005) Dental implant failure rates and associated risk factors. *International Journal of Oral and Maxillofacial Implants* **20**, 569–577.

Roos-Jansåker, A. M., Lindahl, Ch., Renvert, H. & Renvert, S. (2006a) Nine- to fourteen-year follow-up of implant treatment. Part I: implant loss and associations to various factors. *Journal of Clinical Periodontology* **33**, 283–289.

Roos-Jansåker, A. M., Renvert, H., Lindahl, Ch. & Renvert, S. (2006b) Nine- to fourteen-year follow-up of implant treatment. Part III: factors associated with peri-implant lesions. *Journal of Clinical Periodontology* **33**, 296–301.

Strietzel, F. P., Reichart, P. A. A., Kale, A., Kulkarni, M., Wegner, B. & Küchler, I. (2007) Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. *Journal of Clinical Periodontology* **34**, 523–544.

Torrella, F., Pitarch, J., Cabanes, G. & Anitua, E. (1998) Ultrasonic ostectomy for the surgical approach of the maxillary sinus: a technical note. *International Journal of Oral and Maxillofacial Implants* **13**, 697–700.

Vehemente, V., Chuang, S. K., Daher, S., Muflu, A. & Dodson, T. B. (2002) Risk factors affecting dental implant survival. *Journal of Oral Implantology* **28**, 74–81.

Vörös, J., Wieland, M., Ruiz-Taylor, L., Textor, M. & Spencer, N. D. (2001) Characterization of titanium surfaces. In: Brunette, D. M., Tengvall, P., Textor, M. & Thomsen, P. (eds). *Titanium in Medicine*, pp. 87–144. Berlin: Springer.

Weibrich, G., Buch, R. S. R., Wegener, J. & Wagner, W. (2001) Five-year prospective follow-up report of the Astra Tech standard dental implant in clinical treatment. *International Journal of Oral and Maxillofacial Implants* **16**, 557–562.

Wennerberg, A., Albrektsson, T., Andersson, B. & Krol, J. J. (1995) A histomorphometric and removal torque study of screw-shaped titanium implants with three different surface topographies. *Clinical Oral Implants Research* **6**, 24–30.

Wilson, T. G. & Nunn, M. (1999) The relationship between the interleukin-1 periodontal genotype and implant loss. Initial data. *Journal of Periodontology* **70**, 724–729.

Address:
Eduardo Anitua
San Antonio 15, 3° 01005 Vitoria
Spain
E-mail: eduardoanitua@eduardoanitua.com

Clinical Relevance

Scientific rationale for the study: Although the long-term functionality of dental implants is welldocumented, many studies describe simple implant survival in favourable locations and most reports evaluating risk factors for failure are flawed in terms of their statistical analyses. It is therefore important to analyse a large number of implants inserted into different anatomical sites and under different surgical procedures using an implant- and patient-based analysis of failures and identify the risk factors related to implant failure in a statistically valid manner.

Principal findings: Implant staging and the use of special techniques are risk factors for implant failure. Additionally, overall survival rates were 99.2%, 96.4% and 96% for the implant-, surgery- and patient-based analysis, respectively.

Practical implications: The data presented herein contribute to better understanding of the factors associated with implant failure. The latter might help to improve clinical decision-making and thus enhance implant long-term success.