Long-term implant success at the Academy for Oral Implantology: 8-year follow-up and risk factor analysis

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Purpose: Rehabilitation of the incomplete dentition by means of osseointegrated dental implants represents a highly predictable and widespread therapy; however, little is known about potential risk factors that may impair long-term implant success.

Methods: From 2004 to 2012, a total of 13,147 implants were placed in 4,316 patients at the Academy for Oral Implantology in Vienna. The survival rates after 8 years of follow-up were computed using the Kaplan-Meier method, and the impact of patient- and implant-related risk factors was assessed.

Results: Overall implant survival was 97% and was not associated with implant length ($P=0.930$), implant diameter ($P=0.704$), jaw location ($P=0.545$), implant position ($P=0.450$), local bone quality ($P=0.398$), previous bone augmentation surgery ($P=0.617$), or patient-related factors including osteoporosis ($P=0.661$), age ($P=0.575$), or diabetes mellitus ($P=0.928$). However, smoking increased the risk of implant failure by 3 folds ($P<0.001$) and a positive history of periodontal disease doubled the failure risk ($P=0.001$).

Conclusions: Summing up the long-term results of well over 10,000 implants at the Academy for Oral Implantology in Vienna it can be concluded that there is only a limited number of patients that do not qualify for implant therapy and may thus not benefit from improved quality of life associated with fixed implant-retained prostheses.

Keywords: Dental implants, Endosseous dental implantation, Implant-supported dental prosthesis, Periodontal diseases, Risk factors, Survival analysis.

INTRODUCTION

Osseointegrated dental implants represent a highly predictable and widespread therapy for rehabilitation of the incomplete dentition [1]. Reported success rates for oral implants are high; however, there is a lack of longitudinal data with at least 5 years of follow-up [2]. It has been suggested that several risk factors may impair long-term implant survival including jaw location (anterior vs. posterior region and maxilla vs. mandible) [3], implant dimensions (length, diameter, and implant design) [4], simultaneous or staged bone augmentation procedures [5], local bone density at the implant site [6], and patient-related risk factors such as age, smoking, history of periodontal disease, diabetes mellitus, and osteoporosis [7,8].

Rehabilitation with oral implants offers some key advantages over conventional prosthetic treatments because implant therapy conserves the tooth structure in the residual dentition and reduces or eliminates the need for partial or complete removable prostheses.

A prerequisite for predictable implant osseointegration is a sufficient amount of bone volume and satisfactory quality of the bone at the implant recipient site, both of which are frequently compromised when teeth are lost due to chronic inflammation or even trauma. Implant positioning in the available bony crest (bone-demanded implant placement) is dependent on enough alveolar bone to support a fixture at least 8–10 mm long and 3–4 mm in diameter. Bone augmentation using autologous grafts and/or bone substitute materials are used in cases of deficient bone volume as well as to enable favorable three-dimensional implant positioning and beneficial biomechanics (prosthetic-driven implant placement).

The Academy for Oral Implantology, founded in 2004 in Vienna, Austria, has treated over 4,000 implant patients. Meticulous records have been kept of each of the over 13,000 dental implants placed at the Academy. The aim of our retrospective study was to evaluate the long-term survival rates and associated risk factors with dental implants in this large-scale patient cohort.

MATERIALS AND METHODS

A total of 4,316 patients received dental implants at the Academy for Oral Implantology in Vienna from 2004 to 2012. All patients provided written, informed consent to the scientific use of their data. There were 1,780 male (41.2%) and 2,536 female patients (58.8%), respectively. The mean age was 58.6 years (range, 16 years to 102 years), and there were 25 patients aged up to 20 years (0.6%), 175 patients between 21 and 30 years (4.1%), 316 patients between 31 and 40 years (7.3%), 713 patients between 41 and 50 years (16.5%), 1,023 patients between 51 and 60 years (23.7%), 1,053 patients between 61 and 70 years (24.4%), 751 patients between 71 and 80 years (17.4%), 233 patients between 81 and 90 years (5.4%), and 27 patients older than 90 years (0.6%). Smokers comprised 20.3% of the total population, of which 30.5% smoked 1–5 cigarettes per day, 38.1% smoked 6–15 cigarettes per day, and 31.4% smoked at least 16 cigarettes per day. Eighty-one patients had osteoporosis (1.9%) and 92 patients had diabetes mellitus (2.1%). Moreover, 689 patients had a history of periodontal disease (16.0%). Patient demographics are listed in Table 1.

From 2004 to 2012, 13,147 total implants from various manufacturers (mainly Nobel Biocare, Gothenburg, Sweden; Astra Tech AB, Mölndal, Sweden; Dentsply, Mannheim, Germany; and Biomet 3i, West Palm Beach, FL, USA) were placed. The mean implant length was 12.2 mm (range, 5-8 mm): 839 short implants [9] were less than 10 mm in length (5.8%), 3,858 implants were between 10 mm and 12 mm length (29.5%), 7,537 implants were between 13 mm and 15 mm length (58.4%), and 913 implants were longer than 15 mm (6.3%). The mean implant diameter was 4.2 mm (range, 3-6 mm): 2,564 narrow-diameter implants [10] were less than 3.75 mm in diameter (19.5%), 8,887 regular-diameter implants were between 3.75 mm and 4.8 mm in diameter (67.6%), and 1,696 were wide-diameter implants with a width of at least 5 mm (12.9%) [11].

Table 1. Demographic characteristics of the 4,316 patients treated at the Academy for Oral Implantology in Vienna from 2004 to 2012.

Characteristic	Male patients (%)	Female patients (%)
Age (year)		
≤20	2.2	2.0
21–30	4.9	4.2
31–40	9.9	10.3
41–50	23.0	21.2
51–60	22.2	23.7
61–70	25.6	25.2
71–80	9.8	10.2
81–90	2.3	3.1
>90	0.1	0.1
Smokers	19.1	21.2
Osteoporosis	1.2	2.3
Diabetes mellitus	2.4	1.9
Periodontal disease	15.2	16.6

Almost half of the implants (46.3%) were placed in partially edentulous patients who presented with intermediate gaps or free-end edentulism, while 36.5% were placed in edentulous jaws. Single-tooth implants comprised the residual 17.2% of the sample. A total of 7,687 implants (58.5%) were placed in the maxilla and 5,460 implants in the mandible (41.5%). In addition, 4,233 implants replaced anterior teeth such as the incisors or canines (32.2%), while 8,914 implants were placed in the premolar and molar regions (67.8%). Data were collected using impDAT dental software ver. 3.58 (Kea Software, Pöcking, Germany). The following variables were analyzed: implant type, implant length, implant diameter, implant location, bone quality at the implant site, and patient-related risk factors. The Kaplan-Meier curves were used to estimate the 8-year implant survival rates were calculated. In addition, 95% confidence intervals were computed, and log-rank tests were used for subgroup comparisons [12]. All calculations were performed using the R-project software (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The number of dental implants placed at the Academy for Oral Implantology increased significantly from 2004 to 2012 (over 2,000 implants per year), and the failure rate remained stable at 3.0%±0.7% (Fig. 1). The 402 implant failures (out of 13,147 implants placed) were evenly distributed among all of the classes of indication (Table 2). However, single-tooth gaps in the esthetic region of the upper jaw (95.8% survival rate) and completely edentulous maxillae (96.2% survival rate) were identified as the most complex situations of implant rehabilitation in our study popula-

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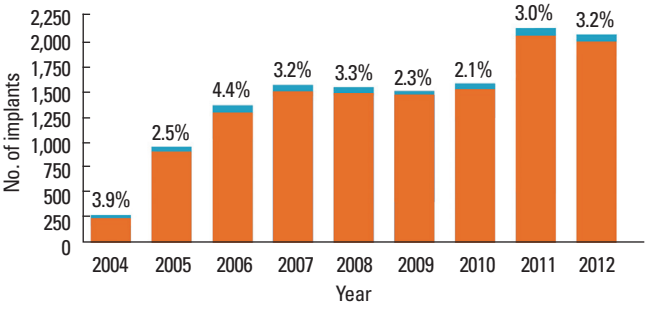

Figure 1. The number of dental implants placed at the Academy for Oral Implantology increased significantly in the years 2004 to 2012 (over 2000 implants per year) while the failure rate remained stable at around 3%.

tion (Fig. 2). The estimated implant survival after 8 years was 94.8% in the mandible compared to 92.6% in the maxilla (Table 3) without significant difference (P=0.545). Implants replacing anterior teeth (incisors or canines) had a 93.5% survival rate that was similar to the survival rate of implants in the posterior region (93.9%, P=0.450). Narrow-diameter implants (less than 3.75 mm in width) demonstarted a similar survival rate of 95.4% compared to wide implants with a diameter of 5 mm or more (95.8%, P=0.704). Short dental implants less than 10 mm in length demonstrated a favorable 8-year survival rate of 96.3% and this rate was not significantly different to the survival of the longer ones (P=0.930).

The number of grafting procedures performed to enhance the bone volume at the implant site had also risen since 2004 with 346 bone grafts in 2012 (Fig. 3). Of the 1,917 bone augmentation procedures, 46% occurred in the maxillary sinus (sinus floor elevation surgery), 9% were fresh extraction sockets (alveolar ridge preservation), 32% were done to increase the alveolar ridge width (horizontal augmentation), and 12% were done to increase alveolar ridge height (vertical augmentation). Implants placed in the augmented maxillary sinus following sinus floor elevation showed a 4-year and 8-year survival rate of 96.6% and 91.4%, respectively. Vertical augmentation using autologous onlay bone grafts in cases of reduced alveolar bone height yielded survival rates of 97.0% at 4 years and of 91.9% at 8 years. Horizontal augmentation in cases of knife-edged residual ridges (Atwood [13] class IV) were less problematic than vertical grafts were, considering that the implant survival rates after 4 and 8 years remained consistent at 95.5% and 95.0%, respectively, and no significant difference between implants inserted into augmented bone and native jawbone was found (P=0.617).

The 8-year survival rate of implants placed in smokers was significantly reduced to 76.5% (P<0.001). This translates into a more than 3-fold increased risk of implant failure among smokers compared to nonsmokers. Moreover, the number of cigarettes smoked per day influenced the failure rate, but implant survival was reduced by only 1% in patients smoking up to five cigarettes a day. Smoking 6–15 cigarettes doubled the risk of implant failure. Periodontal disease was another important factor influencing implant survival. The 8-year survival rate in patients suffering from periodontitis was reduced to 88.6%, which is a 2-fold increased risk of implant failure compared to implants in patients without periodontitis (P=0.001). Approximately one third of all treated patients were smokers and/or suffered from periodontitis; therefore, it not surprising that almost half of all implant failures (43%) occurred in these at-risk patients (Fig. 4).

Table 2. The number and success rates of dental implants achieved in various classes of indication.

Classes of indication	Number of implants	Implant success rate (%)
Free-end gaps in the maxilla	1,816	97.9
Intermediate gaps in the mandible	1,174	97.8
Single-tooth gaps in posterior regions	1,418	97.1
Intermediate gaps in the maxilla	1,774	97.0
Completely edentulous mandible	1,734	97.0
Free-end gaps in the mandible	1,733	96.8
Completely edentulous maxilla	2,845	96.2
Single-tooth gaps in the esthetic region	653	95.8
Total	13,147	97.0

In patients suffering from osteoporosis, the 8-year survival rate (94.4%) was not significantly different from the healthy patients (P=0.661). However, the failure rate was 2% higher in the upper jaw of patients with osteoporosis compared to the lower jaw; thus, reduced bone density may be more influential in the mandible than in the spongy bone of the maxilla. By contrast, reduced local bone density at the site of implant placement (defined as class IV according to Lekholm and Zarb [14]: thin layer of cortical bone surrounding a core of low density trabecular bone of poor strength) was associated with a 2-fold increased risk of implant failure (8-year survival, 84.8%) compared to implants in areas of high bone density, but this finding was not statistically significant (P=0.449). Diabetes is not considered a risk factor for implant survival, if blood sugar levels are effectively controlled. Patients suffering from diabetes demonstrated high long-term survival rates of 95.1% that did not significantly differ from the healthy population (P=0.928). Despite widespread concerns regarding implant survival in senior citizens, there is no evidence that advanced age poses a risk for implant survival. Patients over 70 years of age had an 8-year survival rate of 95.3% that was similar to those younger than 30 years (96.5%, P=0.575). Thus, the majority of patients qualified for implant therapy and was able to benefit from an improved quality of life, which is associated with fixed implant-retained prostheses.

DISCUSSION

Overall implant survival at the Academy for Oral Implantology of 97% compares well to long-term results in international scien-

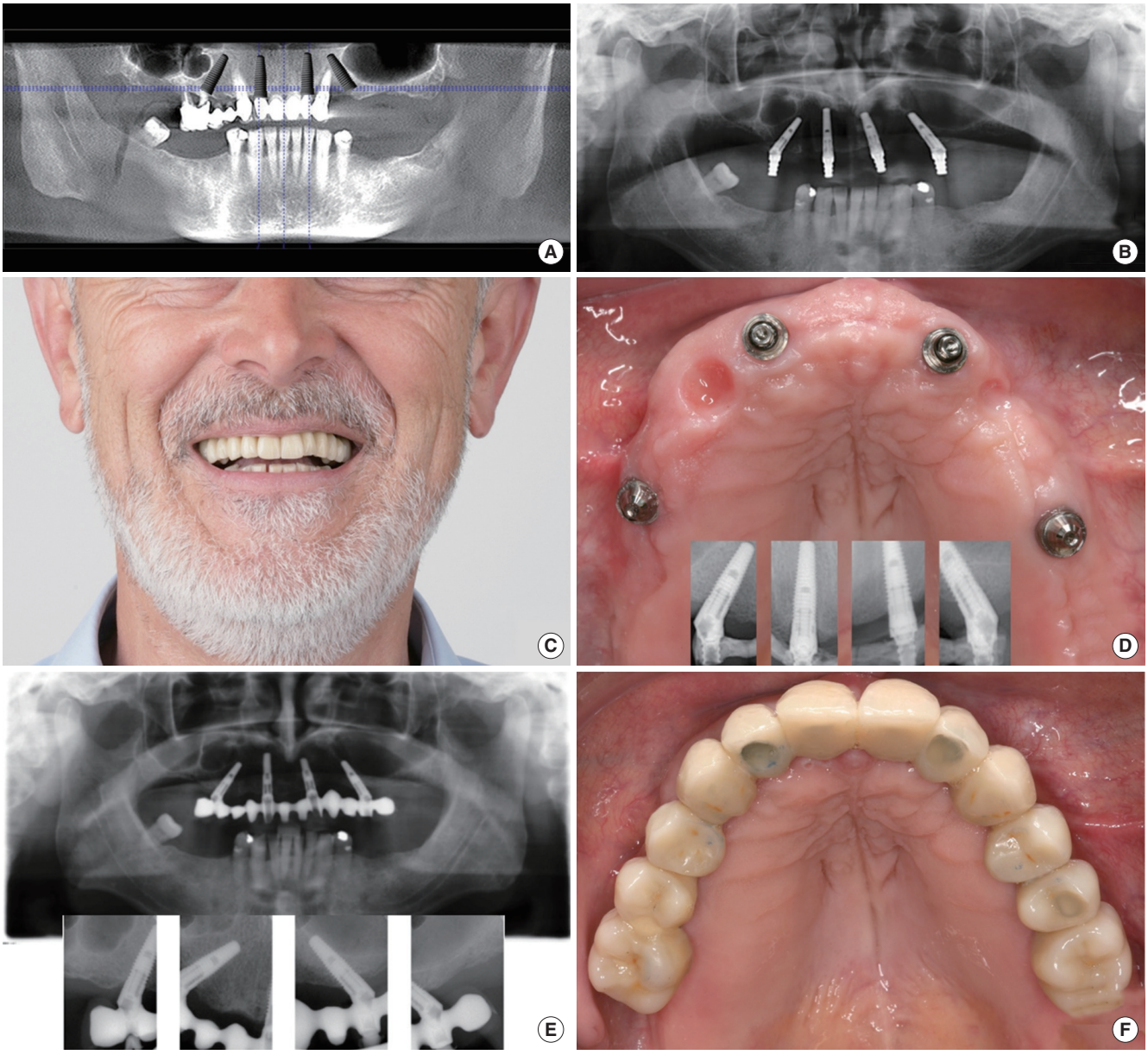

Figure 2. Implant rehabilitation of the completely edentulous maxilla according to the All-on-4 (Nobel Biocare, Gothenburg, Sweden) flapless protocol. (A) Preoperative planning procedure using cone-beam computed tomographic scans, (B) postoperative X-ray with impression copings and angulated multiunit abutments on tilted distal implants, (C) immediate temporary fixed restoration delivered at the day of surgery, (D) pictures and x-rays at final prosthesis delivery, and (E, F) 5 years after implant placement.

tific literature. Charyeva et al. [15] reported a 6-year survival rate of 96%, and Simonis et al. [16] found a cumulative survival rate of 83% after 10–16 years. Moreover, a systematic review by Berglundh et al. [17] summarizing the results of 51 studies (8,588 implants in 2,675 patients) calculated an overall failure rate of 2.5% prior to loading and 2%–5% after 5 years. Our analysis of 13,147 implants in 4,316 patients yielded early failures (prior to or within the first year of loading) in 2.1% and late failures in 0.9%.

The risk factor analysis in our study population yielded findings similar to the results of systematic reviews and meta-analyses. Regarding implant length, Monje et al. [18] reported that short implants had a similar estimated long-term survival; however, peak failure rates of short dental implants occurred earlier (4–6 years) than standard dental implants did (6–8 years). Regarding implant diameter, Sohrabi et al. [19] summarized the survival rates for narrow implants (3.5 mm or less in diameter) and found they are similar to those reported for standard-width implants. In addition, Strietzel et al. [20] agreed that smoking is a significant risk factor

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Table 3. Eight-year implant survival rates for potential risk factors.

Variable	95% Confidence interval
Jaw region	
Mandible	93.6–96.1
Maxilla	90.3–94.9
Implant position	
Incisors/canines	91.0–96.0
(Pre) molars	92.3–95.3
Implant diameter	
Narrow (<3.75 mm)	94.1–96.8
Wide (≥5 mm)	93.4–98.1
Implant length	
Short (<10 mm)	93.6–98.0
Regular (≥10 mm)	92.3–94.7
Sinus floor augmentation	
4 Years	95.5–97.8
8 Years	86.1–96.8
Vertical onlay bone grafts	
4 Years	93.7–100
8 Years	81.7–100
Horizontal onlay bone grafts	
4 Years	93.2–97.8
8 Years	92.5–97.5
Smoking	
Positive	64.4–88.7
Negative	92.5–94.8
Periodontal disease	
Positive	82.9–94.3
Negative	92.1–94.5
Osteoporosis	
Positive	89.9–98.9
Negative	92.4–94.7
Bone quality	
Class I–III	96.6–97.3
Class IV	71.6–97.9
Diabetes mellitus	
Positive	91.6–98.5
Negative	92.4–97.0
Age	
<30 Years	94.0–99.3
>70 Years	94.1–96.4

The 95% confidence intervals were estimated using the Kaplan-Meier method.

of implant failure with an odds ratio of 2.25; we found a 3-fold increased risk our patient sample. An odds ratio of 3.02 and an average of 0.61 mm more marginal bone loss was found in patients

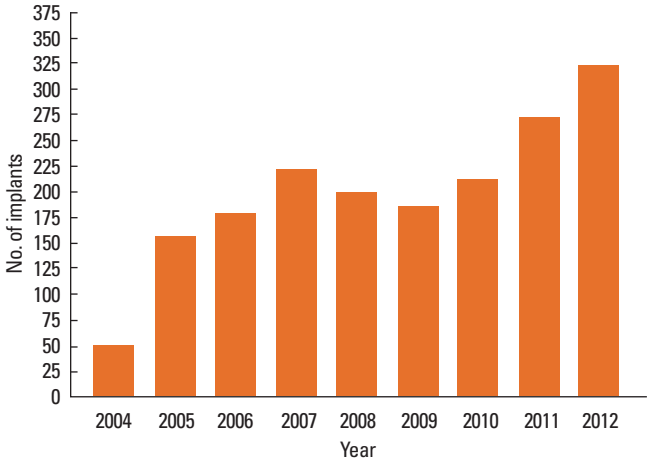

Figure 3. The number of grafting procedures to enhance bone volume for implant insertion (total of 1,917 sinus floor elevation operations, horizontal or vertical block augmentations, and socket grafts).

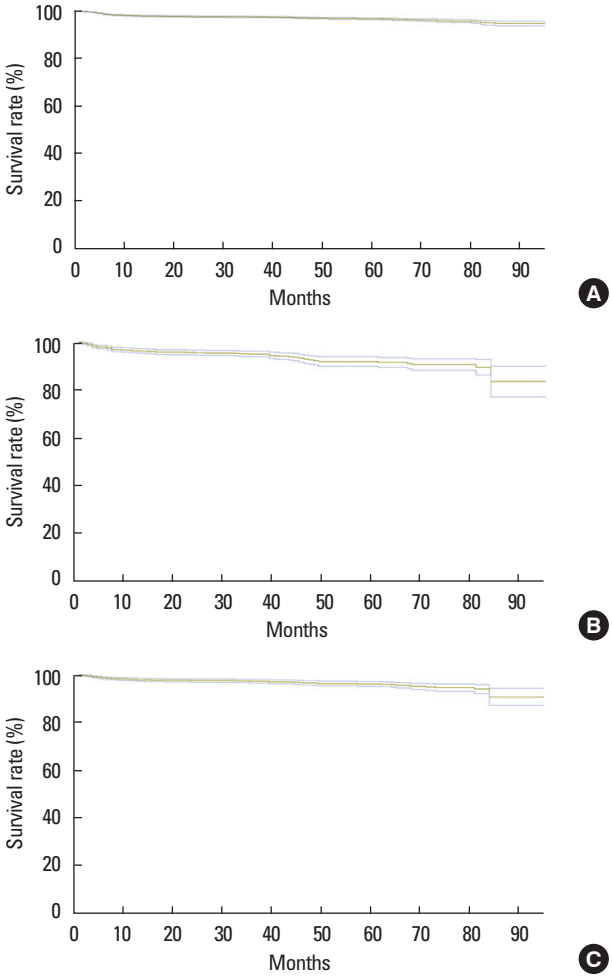

Figure 4. Kaplan-Meier curves (and 95% confidence intervals) for implant survival through 96 months (8 years) in healthy patients (A), smokers (B), and patients suffering periodontal disease (C).

with a history of periodontitis compared to those without a history of periodontitis [21], and we found a 2-fold increased failure risk in our population. Moreover, Bornstein et al. [22] found little evidence to support an association of osteoporosis with implant failure. Regarding diabetes, Salvi et al. [23] found that only poorly controlled diabetes may be a risk factor for increased severity (but not extent) in periodontitis; however, lacking evidence to indicate that implant therapy in subjects with diabetes yields long-term outcomes comparable with those of nondiabetic subjects.

Implant failure in augmented bone was not found to be significantly higher than that in native jawbone. Implants placed in grafted sinuses demonstrated a high survival rate of 97% 4 years after sinus floor elevation surgery (sinus-lift). Results in the literature range from 60% to 100% with a mean survival rate of 95% [24-27]. Implant survival following vertical and horizontal bone augmentation was 97% and compares favorably to the results in the literature of 85% and 99% (range, 76% to 100%) after vertical and horizontal onlay block grafting, respectively, and 98% (range, 77% to 100%) after guided bone regeneration procedures [28-35]. Higher long-term survival rates in horizontal bone grafts than those in vertical bone augmentation are in agreement with recently published results [36].

Summing up the long-term results of 13,147 dental implants placed at the Academy for Oral Implantology in Vienna the following conclusions may be drawn: First, the 402 total implant failures were evenly distributed among all of the classes of indication and resulted in an overall implant survival rate of 97%. Second, the edentulous maxilla and the esthetic zone of the upper jaw can be considered more complex and challenging treatment situations. Third, implants of short length or reduced diameter are routinely used and have comparably high survival rates of more than 95%. Fourth, bone-grafting procedures may also provide satisfactory, long-term survival rates between 90% and 95% in augmented bone. Fifth, smoking and a history of periodontal disease increases the risk of implant failure by 3-fold and 2-fold, respectively. Last, patients suffering from osteoporosis or diabetes have a favorable implant survival of 95% after 8 years of loading. Advanced age, as well, does not seem to pose a contraindication for the placement of dental implants.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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