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Private Practice Results of Screw-Type Tapered Implants: Survival and Evaluation of Risk Factors

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Purpose: *The aims of this study were to examine the long-term survival and the prosthetic treatment outcome of screw-type, tapered implants placed in a private practice setting and to explore potential risk factors of implant failures.* ***Materials and Methods:*** *In this retrospective analysis of patients treated with endosseous screw-type tapered implants, data relative to implant placement and failure, implant length, location, prosthetic treatment, medical history, smoking habits, and oral health behavior were gathered by chart review and questionnaire. An oral examination was also conducted. Cumulative survival rates were estimated through Kaplan-Meier methods. Comparisons between subgroups of patients were made using the log-rank statistical test. The association between several factors and implant failures was analyzed using Cox regression analyses (random and dependent models). Differences were considered significant when* P < *.05.* ***Results:*** *The survival rate of 663 implants placed in 159 patients (65 men, 94 women; 80.7% of 197 eligible patients) was 91.8% after 120 months. Mandibular implants had a higher survival rate than maxillary implants (96% versus 89%,* P = *.011). The failure rates for implants were 15.0% among current smokers, 9.6% among former smokers, and 3.6% among nonsmokers. The differences between nonsmokers, former smokers, and current smokers were significant (nonsmokers versus former smokers:* P = *.036, nonsmokers versus current smokers:* P < *.001, former smokers versus current smokers:* P = *.003). Only number of years of smoking was significantly associated with an increased risk of implant failures (*P = *.036 using dependent estimation;* P = *.004 using independent estimation). The HR increased to 6.6 for patients who had smoked for 45 years. Loosening of prosthetic components were rare (n = 12). No fractures of screws or implants were found.* ***Discussion:*** *Higher failure rates for former smokers and a dose-response effect between duration of smoking and implant failure rates suggested that permanent tissue damage from smoking may occur in addition to immediate local and systemic effects. The frequency of prosthetic complications was comparable to other studies.* ***Conclusions:*** *Screw-type tapered implants placed in a private dental office demonstrated a cumulative survival rate of 91.8%. The relative risk of implant failure increased with the duration of smoking.* INT J ORAL MAXILLOFAC IMPLANTS 2006;21:607–614

Key words: *dental implants, implant failure, life table analysis, smoking, survival rate*

Investigators have conducted prospective and retrospective studies of patients with dental implants to estimate the long-term suitability of implant systems and to assess factors leading to failure. Depending on the implant system, region of placement, prosthetic treatment, and the methods of statistical analysis, different survival and success rates have been reported. Many studies have been published on the long-term results achieved in university clinics,[1–16] but few studies have documented survival rates of implants placed and restored by individual practitioners.[17–20]

In a recent literature review summarizing 17 studies, a 5-year survival rate of 96% (CI: 93% to 98%) was calculated for more than 7,000 implants.[21] Ten-year survival rates in excess of 90% have been demonstrated for most modern implant systems.[6,8,19] Some authors have reported that implant failures occur more frequently in the maxilla than in the mandible,[1,2,8,9,16,20] whereas others have not found such a difference, especially those who examined partially edentulous situations.[6,7,14,15,22]

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Potential risk factors for implant failure include use of an inadequate implant system,[3,12,23] placement in the maxilla or in a posterior site,[1,2,8,9,20] poor bone quality,[24] use of an implant less than 10 mm,[2,4,9,25,26] use of an implant with too large or too small a diameter,[25,27,28] dentoalveolar reconstructive procedures,[9,29] biomechanical overload,[29,30] and placement in a patient with insufficient oral hygiene,[17,20,27] a smoking habit,[16,20,24,30–36] or poor medical status.[16,20,27]

The aims of this study were to examine the long-term survival and the prosthetic treatment outcome of screw-type tapered implants placed in a private practice setting and to explore potential risk factors of implant failures.

MATERIALS AND METHODS

Participants

This retrospective study examined all patients with screw-type tapered implants (Tiolox implants; Dentaurum, Ispringen, Germany) placed, restored, or removed by a single dentist in a private practice setting in Sigmaringen, Germany, between January 1990 and July 1998. All individuals were invited to participate in an examination carried out by 2 clinicians from the University of Greifswald, Germany, in the dentist's office from July to September 2002. The study was approved by the Ethics Committee of the University of Greifswald, and all participants gave their informed written consent.

Data Assessment

Data were collected by means of chart review, oral examination, and a questionnaire regarding medical history, smoking habits, and oral health behavior.

The presence or absence of the following diseases was recorded: cardiovascular diseases, allergies, blood-clotting disorders, diabetes, hepatitis, tuberculosis, human immunodeficiency virus (HIV), thyroid diseases, osteoporosis, arthritis/arthrosis, and rheumatism.

The patients were classified as nonsmokers, former smokers, and current smokers at the time of the follow-up examination. Duration of smoking was computed as the difference between age at smoking initiation and age at smoking cessation or follow-up examination.

Patients were questioned about oral hygiene, including frequency of toothbrushing (3 times per day/twice a day/once a day/less than once a day), usage of other oral hygiene products (eg, dental floss, superfloss, interdental brush, toothpick), last dental appointment (during the last 12 months/more than a year ago), and reason for the last dental appointment (check-up/toothache/general dental treatment/trauma/other).

Examination of the dental status included an assessment of the number of teeth or implants present, their location, and type of denture (removable or fixed). The observations were compared with the patient's charts.

A retrospective study was performed by a chart review to evaluate implant placement, date of implant placement (immediately or number of months after tooth loss), length and diameter of implants, date of prosthesis delivery, type/extension of prosthesis, and surgical and prosthetic complications. Implant failure was defined as need for implant removal or evidence of fracture. Removed and subsequently replaced implants were also considered failures. According to the charts, all patients were examined at least once a year by the clinician who placed the implants.

Statistical Analyses

Cumulative survival rates were computed for all implants (independent estimation) and for 1 implant per patient (dependent estimation) using the Kaplan-Meier estimator from SPSS 11.0 (Chicago, IL).[37] In addition, life table analyses were calculated for subgroups of patients or implant locations. Univariate comparisons between subgroups were made using the log-rank statistical test. The relationship of several specific factors to implant failures was investigated by means of Cox regression analyses using 2 statistical models.

Because some patients had 2 or more implants, it was necessary to consider the possibility of clustered or dependent observations.[2,35] Therefore, the first model considered only 1 implant in each patient. The first implant placed was used for this model; in cases of simultaneous multiple implant placements, an implant was selected using a random number generator. The regression analyses of the first model were performed by SPSS 11.0.

In the second model, all implants were considered, but the correlation of implant observations within the same subject was adjusted using the statistical software SUDAAN 7.5.3 (RTI, Research Triangle Park, NC).

The hazard ratio (HR) was used to estimate the relative risk of implant failures. The design effect is the extent to which the variance generated from a complex (clustering) sample (ie, SUDAAN) differs from that which would have been obtained from a simple random sample (ie, SPSS) of the same size. Greater within-cluster homogeneity and more elements per cluster can substantially increase the design effect. In all statistical analyses, the level of significance was set at $P < .05$.

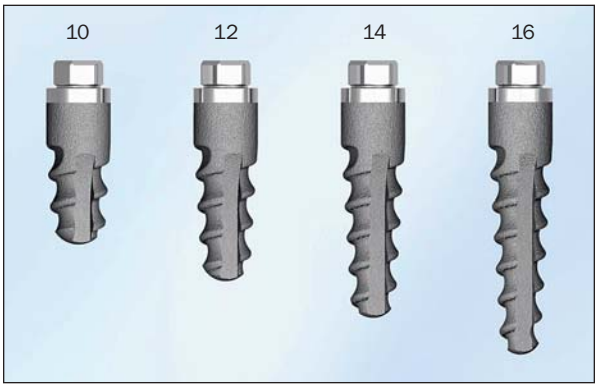

Fig 1 *(Above)* Tiolox implants of various lengths (mm).

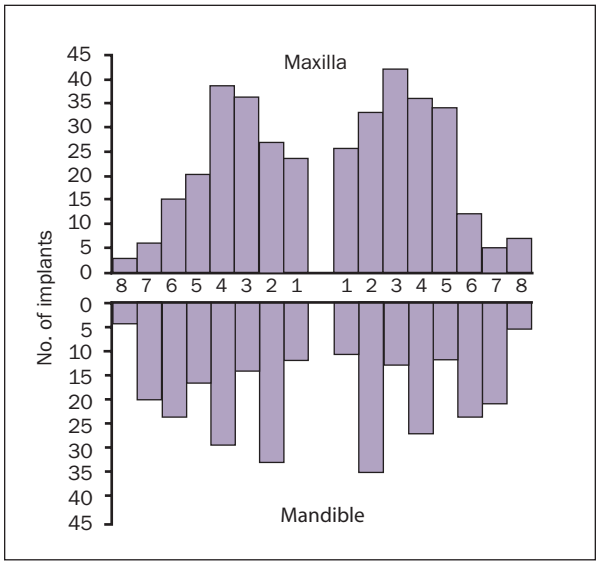

Fig 2 *(Right)* Distribution of maxillary *(top)* and mandibular *(bottom)* implants according to the approximate tooth position (FDI tooth numbering system).

RESULTS

Of the 250 patients who received 1,024 screw-type tapered implants (Fig 1), 33 had moved to an unknown address, 20 had died, and 38 refused to participate. Thus, the final sample comprised 159 patients (65 men, 94 women; 80.7% of 197 eligible patients). The main reasons for nonparticipation were disinterest, lack of time, and general health problems. The patients' age at the time of implant placement ranged from 14.9 to 80.9 years, with a median of 54.1 years. Of 663 implants in the 159 patients, 367 were placed in the maxilla and 296 in the mandible (Fig 2). Most of the maxillary implants were placed in the anterior (n = 191) and premolar region (n = 128). Implants placed in the molar region were observed more often in the mandible (n = 98) than in the maxilla (n = 48). Regarding the number of implants per patient, 27 patients had 1 implant, 26 patients had 2 implants, 36 patients had 4 implants, and 20 patients had 6 implants. Twenty-six patients had more than 6 implants. Implants with lengths of 14 mm (n =199) and 16 mm (n = 283) were more frequently placed than implants of 12 (n = 160) or 10 mm (n = 21). All implants had a diameter of 3.5 mm.

The follow-up period of the patients, ie, the time between the surgical placement and the cross-sectional examination, ranged from 43.6 to 146.3 months, with a mean of 88.2 months.

Of 370 implants with fixed prostheses, 43 were single-tooth replacements, 137 supported implant-supported fixed partial dentures (FPDs; n = 42), and 190 supported tooth/implant–supported FPDs (n = 76). The remaining 293 implants supported 58 bar-retained overdentures. The fixed restorations were either cement- (12%) or screw-retained (88%). The materials used for the fixed prostheses were an alloy with a high noble content and porcelain veneering. Some patients had more than 1 type of prosthetic restoration.

Concerning the dependent Kaplan-Meier estimation (Fig 3), 3 implants failed during the first year after placement, corresponding to a cumulative survival rate of 98.1%. Thereafter, the survival rate was 96.8% after 60 months (5 failures) and 93.5% after 120 months (7 failures).

The Kaplan-Meier survival rate for all placed implants (Fig 4) was 97.6% after 12 months (16 failures in 8 patients), 95.9% after 60 months (27 failures in 13 patients), and 91.8% after 120 months (36 failures in 20 patients). Of the 20 patients with implant failures, 12 lost 1 implant, 6 lost 2 implants, 1 lost 4 implants, and 1 lost 8 implants.

For implants in the mandible, the Kaplan-Meier estimation revealed survival rates of 97.9% after 60 months and 96.0% after 120 months. Maxillary implants demonstrated survival rates of 94.3% after 60 months and 89% after 120 months. The difference in survival rate between the mandible and maxilla was significant both at 60 months (P = .018) and at 120 months (P = .011).

In the anterior region of the mandible, no implant failures were observed after 12 months. One failure

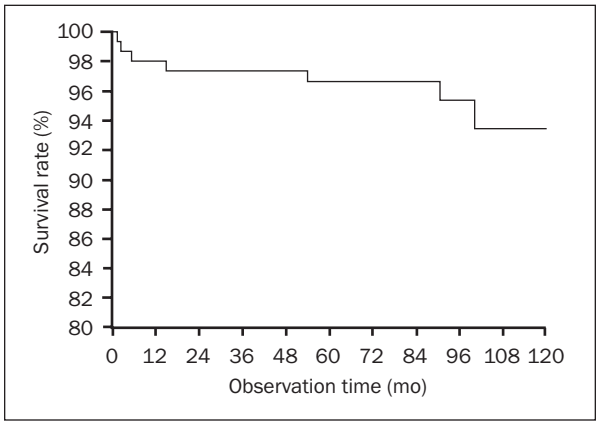

Fig 3 Survival rate curve (1 implant per patient; n = 159).

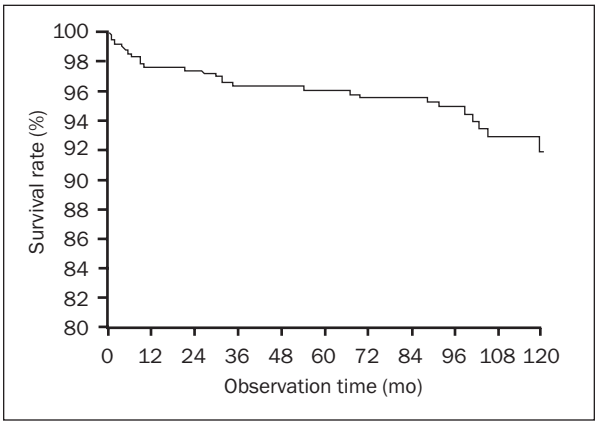

Fig 4 Survival rate curve (all placed implants; n = 663).

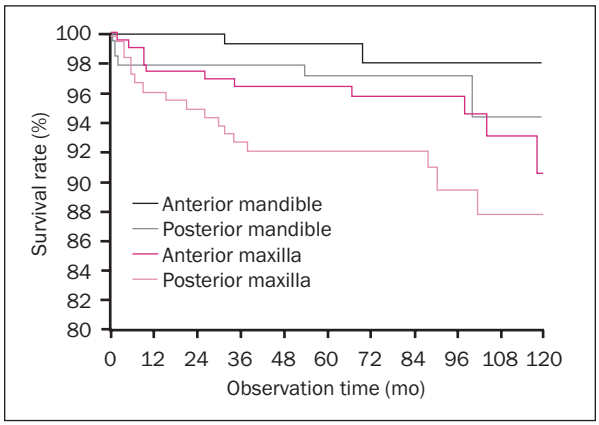

Fig 5 Survival rate as a function of region of placement: anterior maxilla (n = 191), posterior maxilla (n = 176), anterior mandible (n = 115), or posterior mandible (n = 181).

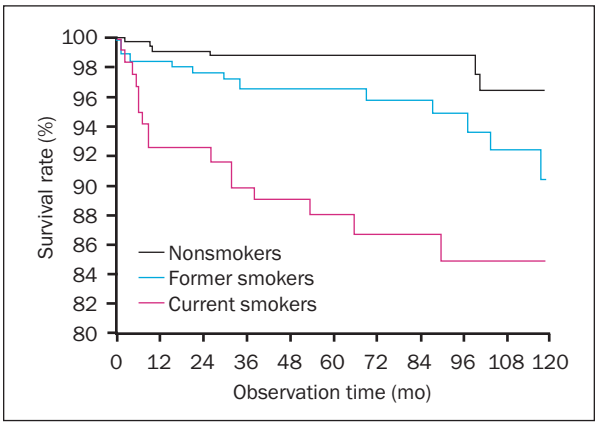

Fig 6 Survival rate as a function of smoking habits: Implants of nonsmokers (n = 294), former smokers (n = 247), current smokers (n = 115).

was observed after 60 months (99.1% survival rate) and 3 failures after 120 months (97.6% survival rate) (Fig 5). The posterior maxillary region showed the lowest survival rates, namely 96% after 12 months, 92% after 60 months, and 88% after 120 months. According to the log-rank test, there were significant differences between anterior mandible and posterior maxilla (P = .008) and between the posterior mandible and posterior maxilla (P = .025).

After 5 years, implants supporting removable dentures had a significantly higher survival rate than implants supporting fixed prostheses (98% versus 94.3%, P = .018); however, there were no significant differences after 10 years (92.9% versus 91.5%, P = .085).

The survival rates for patients who had never smoked were 99.0% at 12 months, 98.6% at 60 months, and 96.4% at 120 months (6 failures of 294 implants), whereas the implant survival rates of current smokers were 92.4% after 12 months, 88.0% after 60 months, and 85.0% after 120 months (16 failures of 115 implants) (Fig 6). Former smokers showed an implant survival rate of 90.4% after 120 months (14 failures of 247 implants). The differences between nonsmokers and former smokers (P = .036), nonsmokers and current smokers (P < .001), and former smokers and current smokers (P = .003) were significant.

The multifactorial Cox regression model for 1 implant per patient showed a significant association between the duration of smoking and increased risk of implant failures (P = .036), as shown in Table 1. The following variables were not significant: age, gender, diseases, various variables of oral health behavior, implant length, region of placement, and suprastructure (fixed or removable). Since duration of smoking was used as a continuous variable, the estimator of the relative risk was calculated by $e^{(\beta \times \text{exposition time})}$. HR was calculated to be 1.52 after 10 years of smoking, 2.31 after 20 years, 3.52 after 30 years, 5.36 after 40 years, and 6.61 after 45 years.

Table 1 Cox Regression Analysis of the Model Considering 1 Implant in Each Patient

	β	SE	*P*	HR	95% CI
Gender (ref: male)	−0.236	0.772	.760	0.79	0.17 to 3.59
Age (continuous)	0.020	0.038	.604	1.02	0.95 to 1.10
Duration of smoking (continuous)	0.042	0.020	.036	1.04	1.00 to 1.08

β = regression coefficient, SE = standard error, HR = hazard ratio, 95% CI = confidence interval.

Table 2 Cox Regression Analysis of the Model Considering All Implants

	β	SE	deff	*P*	HR	95% CI
Gender (ref: male)	−0.783	0.501	1.94	.120	0.46	0.17 to 1.23
Age (continuous)	−0.022	0.020	1.23	.278	0.98	0.94 to 1.02
Region (ref: posterior mandible)						
Anterior maxilla	0.416	0.640	1.43	.517	1.52	0.43 to 5.37
Posterior maxilla	0.996	0.577	1.45	.083	2.71	0.87 to 8.47
Anterior mandible	−0.374	0.835	1.00	.655	0.69	0.13 to 3.58
Prosthesis (ref: fixed)						
removable	−0.335	0.502	1.70	.505	0.72	0.26 to 1.93
Duration of smoking (continuous)	0.043	0.015	2.93	.004	1.04	1.01 to 1.07

deff = design effect.

In a second model (Table 2) of Cox regression analyses, which considered the correlation of implant observations within the same patient, smoking duration was also significant (*P* = .004). The HR of 2.7 for implants placed in the posterior maxilla did not reach significance (*P* = .083). Design effect was the highest for the parameter "duration of smoking" (2.9). The HRs for duration of smoking in this model were 1.54 for 10 years, 2.36 for 20 years, 3.63 for 30 years, 5.58 for 40 years, and 6.92 for 45 years.

Prosthetic complications included screw and abutment loosening, cement dissolution and restoration detachment, and broken restorations, as shown in Table 3. No fractured screws or implants were observed. Minor complications such as loosening of screws or abutments were treated. None of the abutment teeth supporting the 76 tooth-implant–supported FPDs showed signs of intrusion. Repair of overdentures was the most frequent complication, particularly repair related to fractured crowns, broken resin denture base, loose retainers, and fracture of the cast framework. Of the patients (n = 118) with FPDs, 4 required new dentures over 10 years. Of 58 removable prostheses, 5 were remade.

Table 3 Prosthetic Complications Among Fixed (n = 161) and Removable Prostheses (n = 58)

	Complications	
	No.	%
Fixed prostheses		
Screw loosening	6	3.7
Abutment loosening	3	1.9
Cement dissolution	0	0.0
Fracture of porcelain	11	6.8
Replacement	4	2.5
Removable prostheses		
Screw loosening	3	5.2
Abutment loosening	0	0.0
Repair of overdentures	30	51.7
Replacement	5	8.6

DISCUSSION

This retrospective study was the first long-term observation of Tiolox implants. The results from a dentist's private practice demonstrated positive results similar to those achieved in university clinics using various implant systems.[1,3,6,8,10,12,27] The implant survival rate was the lowest in the posterior maxilla and the highest in the anterior mandible. Smoking, whether current or in the past, was found to be a significant risk factor for increased failure of dental implants.

The present study has some limitations that are inherent to retrospective analyses of implants. Removal or fracture of the implant were criteria for implant failure. In retrospective studies such as this one, it is often impossible to consistently ascertain failure in terms other than implant removal (ie, vertical bone loss, implant mobility).[6,10,20,29,34]

Data regarding smoking habits, oral health behavior, and medical history were anamnestic information that were gathered cross-sectionally after completion of treatment. The reliability of these subjective records is lower than that of data from prospective studies.[8,16,20] Other important parameters that might affect the survival rate of implants, such as bone quality or alveolar reconstruction procedures,[9,24,29,34] were not considered because the information in the patients' charts concerning bone quality and quantity before implant placement was imprecise.

For 1 randomly chosen implant per patient, the survival rate in life table analysis was higher (93.5% at 10 years) than that for all placed implants (91.8% at 10 years). It should be considered that the results of a so-called dependent survival curve often cannot be reproduced by a second calculation.[2] The random model produced the largest standard error because it used the smallest sample size.[35]

The failures of 36 implants in 20 patients after 120 months indicate a clustering of observations. However, because the events were highly successful (> 90%), the assumption made with regard to the dependency of observations (dependent or independent) had a smaller effect on Kaplan-Meier estimations.[35]

The overall survival rates of more than 95% after 60 months and more than 90% after 120 months correspond to high survival rates reported by other authors.[3,6,8,10,12,19–22,27] Studies regarding older implant systems showed failure rates of more than 10% after 5 years of observation and more than 15% after 10 years.[1,2,17] Maxillary implants were less successful than mandibular implants in the present study, a finding that supports numerous other studies.[1–3,8,9,16,17,19,20,26] However, some studies have not shown differences in survival rate between the maxilla and mandible, particularly in cases of partially dentate patients.[6,7,14,15,22] Reasons for frequent, but not entirely consistent, findings of lower success rates in the maxilla have included the small amount of bone volume available below the nose,[1] the presence in some cases of extensive maxillary sinus recesses,[1] the generally inferior cancellous bone structure of the maxilla,[2] and the thinner cortical layer of maxillary bone, as well as the lower density of the maxillary spongiosa.[17] Quantitative and qualitative bone deficiencies are often greater in the molar region, which explains why higher failure rates were found for posterior implants in both the maxilla and mandible.[1,19,34] This is in contrast to Haas and coworkers,[2] who observed a higher maxillary failure rate in anterior than in molar regions.

Within the adjusted Cox regression model, the differences between regions of implant placement (maxilla or mandible, anterior or posterior) were not significant; this may indicate confounding by other variables.

Numerous studies have identified current smoking as a risk factor for implant failures.[16,20,24,30–36] In the present study, not only the implants of current smokers but also the implants of former smokers had higher failure rates than implants of nonsmokers. In current smokers, many failed implants were lost during the first year after placement (survival at 12 months: 92.4%), which confirms the results of other authors[31,32] and supports the theory that smoking exerts a number of systemic and local effects on wound healing and epithelialization following implant placement.[33] Nociti and colleagues[36] observed in rats that intermittent cigarette smoke inhalation may result in poor bone quality around titanium implants, which may also lead to less resistance to loading after prosthesis connection. Thus, it may be possible for the clinician to decrease implant complications by encouraging cessation of smoking prior to implant placement.[31,38]

Both with a random implant per patient and with all implants, the calculated HRs of Cox regression analyses increased with smoking duration. The dose-response effects between smoking duration and implant failures were found both for current and former smokers. A possible explanation for this result may be that long-term smokers have permanently altered bone tissue.[34,36]

The final model of Cox regression analysis considered multiple implant failures. The increased design effect for duration of smoking suggests that clustering of implant failures did occur, particularly for smokers. Among 8 patients who lost more than 1 implant, 4 were former smokers and 3 were current smokers. The duration of smoking of these patients ranged from 24 to 47 years. In a retrospective analysis, heavy smoking was 1 factor that was significantly associated with multiple implant failures in maxillae.[30]

The number of complications in the present study was lower compared with other analyses regarding prosthetic treatment outcome.[5,12,20,22,26] Concerning fixed prostheses, other studies showed more problems with screws and abutments, including fracture of screws and implants.[5,11] Loosening or fracture of screws might be associated with the design of the implant-abutment connection.[5,39] The rigid connection between abutment teeth and implants might be the reason that intrusions of abutment teeth were not found within tooth-implant–supported FPDs.[11]

In contrast to other studies, only 3 incidents of screw loosening, and no fracture of screws or abutments, were observed in the group treated with bar-retained overdentures.[12,13] The high proportion of repairs among removable dentures (n = 30) is comparable with the prosthetic treatment outcome of a study in which 23 broken resin denture bases in 87

implant-supported mandibular overdentures were recorded over 6 years.[12]

CONCLUSIONS

Within the limits of a retrospective study design using Kaplan-Meier methods and Cox regression analyses, it can be concluded that in a private practice setting:

- Tapered implants of the Tiolox implant system exhibited a survival rate of 91.8% after 10 years.
- Mandibular implants in the anterior region were most successful, while posterior maxillary implants showed the highest failure rate.
- Both current and former smokers had significantly more implant failures compared to nonsmokers.
- Long-term smoking significantly increased the HR of implant failure from 1.5 for patients who had smoked for 10 years to 5.36 for patients who had smoked for 40 years.
- The frequency of prosthetic complications was lower than in other studies. Loosening of abutments or screws was comparatively rare. No screw or implant fractures were observed.

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