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Factors associated with the survival rate of 4,556 dental implants – a practice-based multicenter retrospective cohort study

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Aim: the objective of the study was to evaluate the influence of systemic and local factors as implant and prosthesis characteristics on the survival rate of dental implants through a practice-based multicenter retrospective cohort study. **Methods:** the sample consisted of 1417 patient records, with 4556 implants placed. Dental records were analyzed considering patients who received dental implants in a period up to 20 years. The complete loss (removal) of the implant was considered a failure. Cox proportional-hazards models were used to evaluate the influence of variables (systemic - age, sex, smoking; local – arch region, previously failed site; implant - shape, length, diameter, thread form, insertion torque; prosthesis - load type, prosthodontics type) on the condition of failed implant. The Backward stepwise selection was then performed based on the probability of the Wald statistic. The measure of effect was the hazard rate (HR). **Results:** a total of 144 implants were lost by the patients (3.2%). The survival rate of the dental implants was 96.8% in a mean time of 5 years. For both Backward stepwise and Enter method, variables that negatively influenced the survival of dental implants were higher total medications (HR=1.511), male sex (HR=1.733), posterior (HR=1.903) and anterior (HR=1.991) maxillary region, previously failed site (HR=3.012), short length (HR=1.742), immediate load (HR=1.896), and overdenture rehabilitation (HR=15.761). Higher survival rate was observed for anterior mandibular region (HR=0.245) and medium (regular) diameter implants (HR=0.450). Age, total diseases, smoking, implant shape, thread form and torque variables did not influence the models. **Conclusion**: it was possible to conclude that either systemic and local patient factors or implant and prosthesis characteristics influence the survival of dental implants.

Keywords: Dental implants. Risk factors. Survival rate.

Introduction

The patient's general health and oral conditions are important factors to be analyzed before the implant-supported prosthetic treatment. In healthy individuals, dental implants might be considered a predictable therapy for replacing lost teeth[1-3]. It is possible to verify an implant survival rate between 85% and 96% over 10 years of follow-up[3-6].

Implant failure is the term used for implants that require removal or have already been lost. The failure or loss of an implant might occur during the osseointegration phase, which may be related to a lack of implant stability, surgical site infection, bone overheating during drilling, or systemic factors of the patient[4,7,8]. On the other hand, delayed failure occurs after the placement and function of the prosthesis and has been related to systemic factors, occlusal overload, parafunction, oral microbiota, and poor hygiene, among others[4,7,8]. Successful rehabilitation depends on the correct conduction of the diagnostic and clinical phases, as well as the rigorous evaluation of the patient's conditions, considering their risk factors[7].

Risk factors for implant therapy represent all general and local conditions that negatively influence the short- and long-term implant survival. The factors have been associated with systemic and local conditions and implant and prosthesis characteristics[4,7]. Examples of some systemic factors that have been considered to significantly reduce the survival rate of dental implants involve habits such as smoking[9,10], diabetes mellitus[10], and the use of drugs such as bisphosphonates[11].

Regarding local factors, there are reports for the negative influence of the previous presence of periodontitis on the survival of dental implants[12], as a higher incidence of implant failures for partially dentate patients with recurrent periodontal diseases in comparison with non-recurrent patients[13]. The location of the implant in the dental arch has shown to influence the survival of implants, with lower survival rates for implants placed in maxilla in comparison with the mandibular sites[14,15] and also lower survival rates for implants placed in posterior maxillary or mandibular regions in comparison with the respective anterior region[14]. Implants placed in a previous lost implant site showed lower survival rates in comparison to implants in pristine sites[15,16].

Considering factors related to implants, it has been reported that modification of the surface topography of implants can alter the healing process[17]. The implant geometry has shown influence on the biomechanical performance, based on implant shape[18,19] and thread form[18]. Short implants have shown different clinical response compared with longer implants (≥ 10 mm)[20]. Differences in survival rate according to implant diameter was also observed[21,22]. Differences in survival rate of implants were depicted based on the insertion torque[23]. For prosthetic factors, the influence of type of prosthesis (single or multiple unit)[14], type of retention (cemented or screw-retained)[24,25], and type of loading (immediate or delayed)[26,27] on the implant survival have been presented.

Although dental implants are applied in systemically compromised patients and in adverse local conditions, it is often unknown whether this therapy is feasible in these patients[1], especially considering the great variability of implants and prosthetic techniques available. In a previous study, around 56% of implants were lost in approximately 4.7% of patients, and it was observed that combinations of risk factors tend to decrease the implant survival rate[28]. Thus, studies with subjects presenting different association of implant risk factors are pertinent, aiming to know groups more propense to implant failure and guiding the clinical practice.

Therefore, the present study aimed to evaluate either the influence of systemic and local factors or implant and prosthesis characteristics on the survival rate of dental implants through a multicenter practice-based retrospective study. The study hypothesis was that systemic, local, or implant and prosthesis factors could negatively influence the implant survival.

Materials and Methods

The present study was approved by the Research Ethics Committee (Number 3.423.981 and CAAE: 13082819.6.0000.5319). The experimental design is a multicenter practice-based retrospective cohort study.

Dental records of private Dental Clinics were analyzed, based on the methods of previous studies[29,30] considering patients who received dental implants from 1999 to 2019. The scope of the sample (patients and implants) was obtained by convenience and composed of dental records of six specialists in Implantology with at least 10-years of experience.

Eligibility criteria for inclusion in the study were: complete dental records with data from patients who returned to the Dental office for follow-up no longer than one year from the date of the study collection. Exclusion criteria were incomplete dental records and dental records of patients who did not return for follow-up or did it before than one year of the data collection.

Data collection was carried out by a calibrated researcher who presented an intra-examiner Kappa score = 0.85. The collected data were tabulated in Excel.

Whenever necessary, doubts related to the treatment of the patient or the data of dental records were clarified by the responsible professional. The collected data were later checked by another researcher, and inconsistencies were reviewed and corrected.

The factors evaluated in the study were divided into: (I) Systemic factors, (II) Local factors and (III) Implant and prosthetic factors.

The patient's systemic factors were collected based on anamnesis and laboratory exams. Data were collected regarding chronic systemic medication (Bisphosphonate, Anti-convulsant, Anti-Hypertensive, Anticoagulant, Antidepressant, hypothyroidism medication, Hormone replacement, Calcium, Gastric Protectant, and cholesterol control, diabetes medication, or Parkinson's disease medication), sex (female or male), age, smoking (smoker and non-smoker), systemic disease (Osteoporosis, Asthma, Hypertension, Hypercholesterolemia, Hypotension, Gastritis, Hepatitis, Dia-

betes, Hyperthyroidism, Depression, Arrhythmia, Hypothyroidism, Convulsion, Rhinitis, Sinusitis, Anxiety, Hepatitis A, Asthmatic Bronchitis, Labyrinthitis, Schizophrenia, Hepatic Steatosis, Sjogren Syndrome, Arthrosis, Fibromyalgia, HPV, Lupus Erythematosus). Patients were included irrespectively of systemic condition.

Regarding local factors, information was collected on the location of the implant in the dental arch (mandible or maxilla, anterior or posterior) and implantation in the site of a previous lost implant.

Implant factors were the length (long ≥13mm, regular ≥10mm and <13mm, short <10mm), diameter (wide ≥5mm, regular <5mm and ≥3.75mm, narrow <3.75mm), shape (cylindrical/conical, cylindrical, conical), thread type (trapezoidal and square, triangular, buttress), insertion torque (≥ 32 N and <32 N), and prosthetic connection (morse taper, external hexagon and internal hexagon). Prosthetic factors were the type of loading (immediate/early and late) and type of prosthesis (multi-unit partial, single, full-arch protocol, overdenture).

The follow-up time, based on the date of the last recorded follow-up appointment, as well as information on the cause of eventual implant failures, were also extracted from the dental records.

Either the survival time or the complete loss of the implant (leading to its removal, regardless of its replacement), were considered as primary outcomes. Survival time was based on the date of the last follow-up appointment recorded.

Data were explored using IBM® SPSS® Statistics 25 software (IBM Corporation, Armonk, NY), and all inferences were carried out with two-tailed tests, considering a test power of 80% (type II error, β=1-0.20) and a significance of 95% (type I error, α=0.05). The frequency of patients in each category of variables was determined for well-maintained and failed implant conditions. A chi-square test was conducted to associate the categories of sex, smoking, region, previously failed site, shape, thread form, length, diameter, torque, load, and prosthodontics with implant condition. For region, shape, thread form, length, diameter, and prosthodontics categories, the chi-square test was adjusted for all pairwise comparisons within a row of each innermost sub-table using the Bonferroni correction. Numerical variables (age, follow-up time, total diseases, and total medications) were related to implant condition using the Spearman correlation test (rho). Total diseases or total medications were considered as the sum of all systemic diseases or drugs reported by the patients, respectively. Survival regression analysis through Cox proportional-hazards models was used to evaluate the influence of variables on the condition of failed implant. Initially, the Enter method was applied to analyze all variables in a block entered in a single step. The Backward stepwise selection was then performed based on the probability of the Wald statistic. At each step, the least significant variable was removed from the model until all the remaining variables had a statistically significant contribution to the model. The measure of effect was the hazard rate (HR), which is the risk of failure, given that the implant has survived up to a specific time.

Results

The sample of this study consisted of 1417 patient records, with 4556 implants placed. The median age of patients at the time of implant placement was 62 years (interquartile range 54 – 71 years). Regarding the patient's sex, 644 (45.5%) were women, and 769 (54.3%) were men. The number of implants placed per patient ranged from a minimum of 1 to a maximum of 20 implants. The mean follow-up time was 5 years. A detailed description of the frequencies and relationships obtained in the study for each covariate can be seen in Table 1. Survival rate of implants at mean of covariates is presented in Figure 1A-H.

Table 1. Frequency of categorical and continuous variables according to implant survival (N = 4556)

Variables	Well-maintained		Failed		Statistical	
Continuous	**Mean**	**SD**	**Mean**	**SD**	**Rho value**	**P value**
Age	61,5	12,7	62,7	14,5	0.022	0.169
Follow-up time	5,0	3,8	1,3	2,0	-0.214	**0.010**
Total diseases	0,5	0,8	0,3	0,7	-0.026	0.081
Total medications	0,3	0,8	0,4	1,0	-0.017	0.248
Categorical	**n**	**Percentage**	**n**	**Percentage**	**Chi-square value**	**P value**
Sex					4.580	**0.032**
Female	2079[a]	47.2%	55[b]	38.2%		
Male	2322[a]	52.8%	89[b]	61.8%		
Smoking					2.107	0.147
Not	3935[a]	91.6%	133[a]	95.0%		
Yes	363[a]	8.4%	7[a]	5.0%		
Region						
Posterior mandibular	1636[a]	37.2%	46[a]	32.4%	6.450	0.092
Posterior maxillary	1207[a]	27.4%	43[a]	30.3%		
Anterior mandibular	583[a]	13.2%	12[a]	8.5%		
Anterior maxillary	975[a]	22.2%	41[a]	28.9%		
Failed site					27.946	**0.000**
Not	4328[a]	98.1%	132[b]	91.7%		
Yes	84[a]	1.9%	12[b]	8.3%		
Shape					2.359	0.307
Cylindrical	3131[a]	71.0%	98[a]	68.1%		
Tapered	440[a]	10.0%	20[a]	13.9%		
Cylindrical/Tapered	841[a]	19.1%	26[a]	18.1%		

Continue

Continuation						
Thread form					9.142	**0.010**
Square/Trapezoidal	748[a]	17.0%	25[a]	17.4%		
Triangular	2796[a]	63.4%	105[b]	72.9%		
Buttress	868[a]	19.7%	14[b]	9.7%		
Length					13.595	**0.001**
Long	1424[a]	32.3%	36[a]	25.0%		
Medium	1973[a]	44.7%	56[a]	38.9%		
Short	1015[a]	23.0%	52[b]	36.1%		
Diameter					13.451	**0.001**
Wide	202[a]	4.6%	14[b]	9.7%		
Medium	3225[a]	73.1%	88[b]	61.1%		
Narrow	984[a]	22.3%	42[a]	29.2%		
Torque					8.503	**0.004**
≥32 Ncm	3710[a]	84.1%	134[b]	93.1%		
<32 Ncm	702[a]	15.9%	10[b]	6.9%		
Load					1.734	0.188
Delayed	2898[a]	67.4%	83[a]	61.9%		
Immediate	1404[a]	32.6%	51[a]	38.1%		
Prosthodontics					71.417	**0.000**
Single	2481[a]	56.2%	72[a]	50.0%		
Multi-unit partial	770[a]	17.5%	27[a]	18.8%		
Full-arch Protocol	1036[a]	23.5%	23[b]	16.0%		
Overdenture	125[a]	2.8%	22[b]	15.3%		

Data loss was minimal for sex (0.2%), smoking (2.6%), region (0.3%), load (2.6%), total diseases (2.5%) and total medications (4.3%)
SD: Standard deviation
Different lowercase letters denote significant difference ($P < 0.05$)

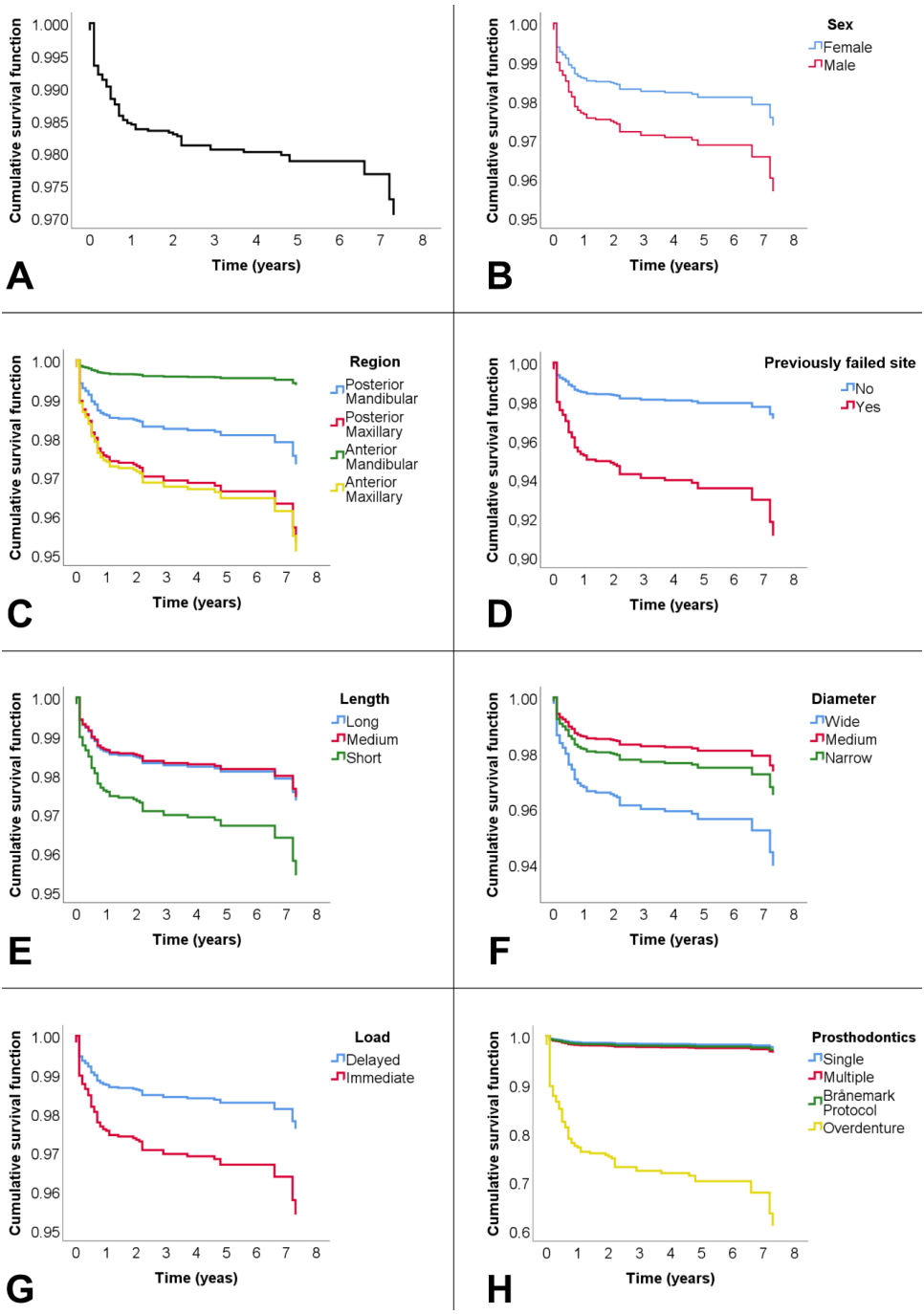

Figure 1. Survival rate of implants at mean of covariates (A); Survival Function for Sex (B), Region (C), Previously failed site (D), Length (E), Diameter (F), Load (G), and Prosthodontics (H).

There was a week significant correlation between implant survival and follow-up moment that the implant failed (Rho = -0.214, P = 0.010) (Table 1). In total, 144 (3.2%) implants were lost, accounting for a survival rate of 96.8%. (Figure 1A). By considering the follow-up periods more specifically, as displayed in table 2, it could be observed that most implants (n=40, 28.0%) were lost within 36 days to 6 months (P < 0.0001), and after 9 years, no loss was observed (Table 2).

Table 2. Frequencies of follow times according to implant condition (N = 4556)

Follow-up time	Well-maintained		Failed	
	n	Percentage	n	Percentage
Immediate	30[a]	0.7%	7[b]	4.9%
Days				
≤36	37[a]	0.8%	34[b]	23.6%
≤180	260[a]	5.9%	40[b]	27.8%
Years				
1	280[a]	6.3%	27[b]	18.8%
2	547[a]	12.4%	8[b]	5.6%
3	529[a]	12.0%	11[a]	7.6%
4	543[a]	12.3%	2[b]	1.4%
5	398[a]	9.0%	4[b]	2.8%
6	331[a]	7.5%	0[1]	0.0%
7	218[a]	4.9%	3[a]	2.1%
8	269[a]	6.1%	8[a]	5.6%
9	182[a]	4.1%	0[1]	0.0%
10	225[a]	5.1%	0[1]	0.0%
11	177[a]	4.0%	0[1]	0.0%
12	146[a]	3.3%	0[1]	0.0%
13	93[a]	2.1%	0[1]	0.0%
14	59[a]	1.3%	0[1]	0.0%
15	38[a]	0.9%	0[1]	0.0%
16	24[a]	0.5%	0[1]	0.0%
17	7[a]	0.2%	0[1]	0.0%
18	10[a]	0.2%	0[1]	0.0%
19	9[a]	0.2%	0[1]	0.0%
Statistical	Chi-square value	699.853	P value	**0.000**

[1]This category is not used in comparisons because its column proportion is equal to zero.
Different lowercase letters denote significant difference ($P < 0.05$)

Association was found between implant condition and sex, previously failed site, thread forms, length, diameter, torque, and prosthodontics variables (P < 0.05) (Table 1). The proportion of failed implants was higher for males (P = 0.032). The per-

centage of failed implants was also higher when an implant was placed in a previously failed site (P < 0.0001). Ratios of well-maintained and failed implants were similar for square/trapezoidal thread forms. However, the proportion of failed implants was higher for triangular than for buttress forms (P = 0.010). The loss was the same for long and medium length and medium diameter and narrow implants but higher when short or wide implants were installed, respectively (P = 0.001). Higher implant failure was related to torque >32 Ncm (p = 0.004). Moreover, better and worse results were obtained with the Brånemark protocol and overdenture, respectively (P < 0.0001).

For each implant condition, the proportion of patients in each category of smoking, region, shape and load, age, total diseases and total medications were similar (Table 1).

Regression using the Enter method (Table 3) showed that the variables that negatively influenced the survival of dental implants were higher total medications (P = 0.005; HR = 1.511; 95%CI = 1.129 – 2.023), male sex (P = 0.015; HR = 1.733; 95%CI = 1.110 – 2.705), posterior (P = 0.013; HR = 1.903; 95%CI = 1.146 – 3.161) and anterior (P = 0.017; HR = 1.991; 95%CI = 1.130 – 3.510) maxillary region, previously failed site (P = 0.002; HR = 3.012; 95%CI = 1.488 – 6.095), short length (P = 0.048; HR = 1.742; 95%CI = 1.004 – 3.023), immediate load (P = 0.007; HR = 1.896; 95%CI = 1.189 – 3.026), and overdenture rehabilitation (P = 0.000; HR = 15.761; 95%CI = 7.028 – 35.344). Higher survival rate was observed for anterior mandibular region (P = 0.001; HR = 0.245; 95%CI = 0.106 – 0.566) and medium (regular) diameter (P = 0.022; HR = 0.450; 95%CI = 0.228 – 0.891). Age, total diseases, smoking, shape, thread form and torque variables did not influence the model.

Table 3. Cox proportional-hazards model for failed implants by Enter method (N = 4556)

Explanatory variables	B	SE	P value	Hazards ratio	95% confidence interval	
					Inferior	Superior
Age*	0.004	0.009	0.677	1.004	0.987	1.021
Total diseases*	-0.220	0.203	0.279	0.802	0.539	1.195
Total medications*	0.413	0.149	**0.005**	**1.511**	1.129	2.023
Sex	0.550	0.227	**0.015**	**1.733**	1.110	2.705
Smoking	-0.043	0.434	0.921	0.958	0.409	2.243
Posterior mandibular	-	-	**0.000**	**-**	-	-
Posterior maxillary	0.643	0.259	**0.013**	**1.903**	1.146	3.161
Anterior mandibular	-1.405	0.427	**0.001**	**0.245**	0.106	0.566
Anterior maxillary	0.689	0.289	**0.017**	**1.991**	1.130	3.510
Failed site	1.103	0.360	**0.002**	**3.012**	1.488	6.095
Cylindrical	-	-	0.552	-	-	-
Tapered	0.143	0.320	0.655	1.154	0.616	2.160
Cylindrical/Tapered	0.347	0.328	0.290	1.414	0.744	2.688

Continue

Continuation						
Square/Trapezoidal	-	-	0.528	-	-	-
Triangular	0.382	0.347	0.272	1.465	0.741	2.894
Buttress	0.156	0.437	0.721	1.169	0.496	2.753
Long	-	-	**0.046**	-	-	-
Medium	-0.038	0.248	0.879	0.963	0.592	1.567
Short	0.555	0.281	**0.048**	**1.742**	1.004	3.023
Wide	-	-	**0.041**	**-**	-	-
Medium	-0.798	0.348	**0.022**	**0.450**	0.228	0.891
Narrow	-0.476	0.400	0.234	0.621	0.283	1.361
Torque	-0.523	0.391	0.181	0.593	0.275	1.277
Load	0.640	0.238	**0.007**	**1.896**	1.189	3.026
Single	-	-	**0.000**	**-**	-	-
Multi-unit partial	0.266	0.289	0.357	1.305	0.740	2.300
Full-arch Protocol	0.188	0.321	0.559	1.206	0.643	2.263
Overdenture	2.758	0.412	**0.000**	**15.761**	7.028	35.344

*Continuous variable.
B = partial regression coefficient; SE = standard error

After improve model by the Backward stepwise method, the following variables were sequentially excluded in seven steps: age, shape, thread form, total diseases, and torque, respectively (Table 4). It can be seen that the variables that negatively influenced the survival of dental implants were practically the same: higher total medications (P = 0.007; HR = 1.136; 95%CI =1.078 – 1.608), male sex (P = 0.010; HR = 1.770; 95%CI = 1.146 – 2.734), posterior (P = 0.026; HR = 1.765; 95%CI = 1.070 – 2.911) and anterior (P = 0.029; HR = 1.858; 95%CI = 1.065 – 3.242) maxillary region, previously failed site (P = 0.001; HR = 3.178; 95%CI = 1.579 – 6.397), short length (P = 0.044; HR = 1.743; 95%CI = 1.015 – 2.991), immediate load (P = 0.005; HR = 1.943; 95%CI = 1.223 – 3.088), and overdenture rehabilitation (P = 0.000; HR = 20.127; 95%CI = 9.686 – 41.823). Similarly, higher survival rate was observed for anterior mandibular region (P = 0.001; HR = 0.236; 95%CI = 0.103 – 0.542) and medium (regular) diameter (P = 0.015; HR = 0.432; 95%CI = 0.220 – 0.850).

Table 4. Cox proportional-hazards model for failed implants by Backward Wald method (N = 4556)

Explanatory variables	B	SE	P value	Hazards ratio	95% confidence interval	
					Inferior	Superior
Total medications*	0.275	0.102	**0.007**	**1.316**	1.078	1.608
Sex	0.571	0.222	**0.010**	**1.770**	1.146	2.734
Posterior mandibular			**0.000**			

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Continuation						
Posterior maxillary	0.568	0.255	**0.026**	**1.765**	1.070	2.911
Anterior mandibular	-1.444	0.424	**0.001**	**0.236**	0.103	0.542
Anterior maxillary	0.620	0.284	**0.029**	**1.858**	1.065	3.242
Failed site	1.156	0.357	**0.001**	**3.178**	1.579	6.397
Long			**0.038**			
Medium	-0.035	0.247	0.889	0.966	0.595	1.568
Short	0.555	0.276	**0.044**	**1.743**	1.015	2.991
Wide			**0.037**			
Medium	-0.839	0.345	**0.015**	**0.432**	0.220	0.850
Narrow	-0.558	0.384	0.146	0.572	0.270	1.214
Load	0.664	0.236	**0.005**	**1.943**	1.223	3.088
Single			**0.000**			
Multi-unit partial	0.345	0.282	0.222	1.412	0.812	2.454
Full-arch Protocol	0.208	0.312	0.506	1.231	0.668	2.268
Overdenture	3.002	0.373	**0.000**	**20.127**	9.686	41.823

*Continuous variable.
B = partial regression coefficient; SE = standard error

Discussion

The hypothesis tested in the study that systemic and local factors and prosthesis and implant characteristics could affect the survival of dental implants, was accepted. Overall, the survival of dental implants was 96.8% after up to 20 years of follow-up (Figure 1A), corroborating with some studies that show survival of 94.6% after 13 years of follow-up[31] and 96.7% after 10 years of follow-up[4]. Most implants were lost (n=40, 28.0%) within 36 days to 6 months, and after 9 years, no loss was observed. The prevalence of early failures of dental implants has also been presented in the literature[3,14,32]. This suggests that systemic and local factors of the patient, as well as factors related to the surgical process (such as surgical site infection and bone overheating during drilling), tend to prevail with respect to causes of implant loss[3,14,32].

It was observed lower survival rate of dental implants in patients with chronic use of systemic medication. Although, a description of the specific types of medication with the greatest influence was not possible due to the low percentage of each type of medication in this analysis. Previous studies corroborate the findings regarding the influence of systemic conditions on implant failure. Studies have reported that patients who use antidepressants showed an association with implant failure due to serotonin being present in the bone and regulating the activation and differentiation of the osteoclasts, which may negatively influence the osseointegration process[33,34]. Chrcanovic et al.[28] showed an association between the intake of proton pump inhibitors and an increased probability of dental implant failure. Reduced acidity in the stomach impairs intestinal absorption of dietary calcium. Thus, there may be a decrease in calcium absorption, as calcium balance is essential for the

maintenance of bone health, it seems reasonable to believe that the imbalance may, to some degree, affect osseointegration[35]. On the other hand, a cohort study showed that the implant survival rate was significantly higher when patients were on antihypertensive medication. The failure rate was almost seven times lower in antihypertensive drug users (0.6%) than in non-users (4.1%). These drugs exert their effect on blood pressure by inhibiting the β-adrenergic receptors responsible for bone resorption, resulting in increased bone accumulation[36].

The present analysis has shown that the male sex presented a significant factor for implant failure compared to women (Figure 1B). Another study also observed the same outcomes[37]. This might be associated to factors such as bite force[38], oral hygiene, and alcohol consumption[39].

Implants placed in the maxilla (anterior and posterior regions) have shown significantly lower implant survival than those in the mandibular arch (Figure 1C). Moreover, the highest survival rate in this study was observed for the anterior mandibular region. Two previous studies also agreed with such outcomes[14,15]. The improved survival rate of implants placed in the anterior mandible in relation to the maxilla may be related to the usually improved bone quality, and greater bone volume found in the anterior mandible, even years after teeth extraction in this region[14].

Dental implants replacing failed implants had lower survival rates than the rates reported for the previous attempts of implant placement (Figure 1D). This agrees with two previous retrospective studies[15,16], which suggested that a site-specific negative effect may be associated with this phenomenon. One study also observed that other factors might potentially influence the failure rate, such as the intake of antidepressants and antithrombotic agents[16]. It might be worth to mention that another study has shown that replaced implants, after osseointegrated, showed the same pattern of marginal bone loss than implants placed in pristine sites[40].

Short implants showed a significant lower survival rate in this study (Figure 1E). Another retrospective study has also shown that short implants have lower survival rates[20]. Shorter implants seem to fail more often than longer ones because of decreased initial stability, lower resistance to bending moment forces, and an increased risk of movement at the interface[28]. Moreover, obviously, any eventual initial bone loss would be more deleterious to short implants than to longer ones. However, a meta-analysis showed similar survival rates for extra-short (≤6 mm) and longer (≥10 mm) dental implants at 1 and 3 years of follow up. The authors concluded that the long-term effectiveness of extra-short dental implants should be further explored[41].

Immediately loaded implants showed significant lower survival rates in this study than those subjected to delayed load (Figure 1G). The literature shows specific data about immediate loading on different types of prosthetic treatment. Immediate loading in the fully edentulous jaw by means of a fixed prosthesis is a well-documented treatment concept. In the mandible, the use of four implants leads to a failure rate of 0 - 3.3%, being a predictable treatment[26]. However, immediately loaded single implants have lower survival rates than the delayed approach, ranging from 85.7 - 100% in studies included in a critical review[26]. In fact, a meta-analysis demonstrated a five times

higher risk of failure for immediately loaded single implants compared with delayed loading[27]. The implants immediately loaded by practitioners in this study were those that, in general, achieved an initial toque > 32 N.cm. However, despite the adequate initial implant stability, other factors play a significant role in the success of osseointegration for immediate implants, such as prosthetic design, occlusal adjustement, biofilm control and presence of parafunctional habits.

Overdentures have been associated with significantly lower implant survival than single- or multi-unit fixed partial prostheses in this study (Figure 1H). The failure rate of implants associated with overdentures was 17.6% (22 failures out of 147 implants). This high failure rate agrees with a previous retrospective study that evaluated implants with follow-ups of at least 20 years, in which the failure rate for implants retaining overdentures was 27.2% (9 failures out of 33 implants)[14]. It is important to note that the proper use of overdentures is more patient-dependent than the other types of (fixed) prostheses. This might have influenced the outcomes of this treatment.

Regular diameter implants were at a greater survival rate in the present study (Figure 1F). It might be considered that they tend to preserve more surrounding bone in comparison to wide implants and have greater bone-to-implant contact for stress dissipation in comparison to narrower implants. A previous meta-analysis has shown that narrower implants (<3.3 mm) had significantly lower survival rates compared with wider implants (≥3.3 mm)[21]. A review showed that narrow implants <3.0 mm performed clinically inferiorly than regular ones, which was not the case for those for other categories (3 - 3.25 mm or 3.3 - 3.5 mm)[22]. Another point to consider is that, in the present study, the wider implants are frequently those of shorter length, which might help to explain the significant lower survival in comparison to the implants of regular diameter.

As limitations of this study, it can be pointed out that only medical records were evaluated, and not the patients clinically, so only the survival of dental implants was evaluated and not the success rate. Specific systemic alterations or medications might alone influence implant survival, but in the present analysis, they could not be evaluated separately due to the limited number of individuals in each category. The study included patients treated from 1999 and significant evolution occurred at implant systems since them, which might also affect the survival rate.

Through the analysis of the data of this study, it was possible to conclude that: (I) Systemic and local factors and implant and prosthetic characteristics influence the survival of dental implants; (II) Variables that negatively influenced the survival of dental implants were higher total medications, male sex, posterior and anterior maxillary region, previously failed site, short length implants, immediate load, and overdenture rehabilitation; (III) A higher survival rate was observed for the anterior mandibular region and regular-diameter implants; (IV) Age, total diseases, smoking, implant shape, thread form, and torque variables did not influence the models.

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Conflict of interest

The authors declare no conflict of interest.

Author Contribution

Angélica Maroli: Acquisition of data, Drafting the article. **Pedro Henrique Wentz Tretto:** Acquisition of data, Drafting the article. **Rafael Sarkis-Onofre:** Conceptualization, Revising it critically for important intellectual content. **Alfonso Sánchez-Ayala:** Formal analyses, Revising it critically for important intellectual content. **Ataís Bacchi:** Conceptualization, Drafting the article, Revising it critically for important intellectual content. All authors actively participated in the discussion of the manuscript's findings, revised, and approved the final version of the manuscript.

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