

Failure of Dental Implants and Associated Risk Factors in a University Setting

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Purpose: To assess the cumulative failure rate of 4,842 implants comprising six commercial implant brands in a university setting, and to evaluate the influence of different risk factors on the implant failure rate. **Materials and Methods:** A retrospective chart review was conducted in patients receiving dental implants at the School of Dentistry of the International University of Catalonia (Barcelona, Spain) from 2011 to 2018. The inclusion criterion was patients presenting at least one failed implant. **Results:** The cohort study included 1,510 patients who received a total of 4,842 implants. The cumulative failure rate was 4.9% and 10.8% at the implant and patient levels, respectively. The multiple regression analysis showed that for the same number of implants per patient, variables such as age and sex were not associated with higher implant failure rates. Furthermore, in considering the combination of arch-sector, a statistically significant reduction in failure rate was observed in the posterior maxilla (OR = 0.66, $P = .038$) and in the posterior mandible (OR = 0.64, $P = .037$). The results showed all implant brands offering high implant survival rates (> 91%). Nobel Biocare and Straumann implants significantly reduced the risk of implant failure (OR = 0.37, $P = .021$ and OR = 0.53, $P = .024$, respectively), while no significant differences were recorded among Klockner (2.8%), MIS (5.4%), Biomet 3i (7.1%), and Astra Tech (8.4%; $P \geq .05$). No association was found between implant loss and bone augmentation, time of implant placement, smoking, and history of periodontal disease. **Conclusion:** The implant failure rates obtained in a university setting resulted in overall cumulative rates of 4.9% and 10.8% at the implant and patient levels, respectively, over a 7-year period. Male sex and implants placed in the anterior mandible may be associated with a higher risk of implant failure. Nobel Biocare and Straumann implants seem to positively affect implant survival rate. *Int J Oral Maxillofac Implants* 2022;37:455–463. doi: 10.11607/jomi.9204

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Dental implants are widely accepted in the dental community as a predictable treatment option over the long term for replacing missing teeth in partially or totally edentulous patients. Osseointegration, originally defined by Brånemark et al¹ as “a direct structural and functional connection between ordered living bone and the surface of a load-carrying implant,” is essential for long-term implant survival. In the last 50 years, implant dentistry has progressed both at macro- and micro-implant level. Up until the end of the 1980s, the

screw-type implant market was dominated by two main surfaces: machined and rough titanium plasma-sprayed surfaces, used by Brånemark and the Schroeder International Team for Implantology, respectively.² Between 1985 and 2000, when major progress was observed in implant dentistry, new surfaces were investigated, resulting in moderately rough surfaces as the best option.² Such implant advances have sought to enhance bone-to-implant contact^{1,3,4} and consequently improve long-term implant success.⁵ The shift from machined to moderately rough surfaces resulted in improved bone apposition and faster integration, leading to shortening of treatment times and the possibility of new loading protocols, such as immediate or early implant loading.^{2,6}

Many implant success criteria have been established by different authors since 1975.⁷ In this regard, it is important to distinguish between implant survival and success. Buser et al⁸ defined success as “the absence of peri-implant infection, absence of pain or subjective discomfort, absence of a continuous radiolucency around the implant, and absence of clinically detectable implant mobility,” while survival is defined as an implant that is still in function, without considering the success criteria.⁹

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Despite the high dental implant survival rates reported in the literature,^{10–12} implants are not exempt of complications, which lead to eventual implant failure. Implant failures are commonly divided into early or late, depending on whether they occur before or at abutment connection or after occlusal loading, respectively.¹³ Different risk factors can condition implant failure. Such factors are divided into patient-related factors (general health, smoking habits, history of periodontal disease, uncontrolled diabetes mellitus, oral hygiene, etc), surgical technique and implant-related factors (timing of implant placement, implant location, dimensions, surface treatment, etc), and implant prosthesis-related factors (loading, retention method, occlusal scheme, etc).^{14–16} In addition, the sex and age of the patient and the clinical experience of the operator may influence implant failure,^{11–13,17–19} though no clear consensus in this regard has been established to date. Furthermore, the dental implant industry has produced a broad variety of implant brands, with different geometric and surface characteristics and different macrodesigns and microdesigns. In this respect, there appears to be no clear evidence of the superiority of one brand over the rest.^{5,20}

Several epidemiologic articles analyzing risk factors for implant failure are based on samples from private practices and not university clinics. The authors considered that evaluating data from a university setting would allow for representative samples (high volume of patients); therefore, the primary objective of the present retrospective cohort study was to assess the cumulative failure rate of 4,842 implants comprising six commercial implant brands during the period between 2011 and 2018 in a university setting. The secondary objective was to evaluate the influence of different risk factors with implant failure.

MATERIALS AND METHODS

The present study was conducted in a population of 1,510 patients who received a total of 4,842 implants in a university setting. The research protocol was approved by the Research Ethics Committee of the International University of Catalonia (Ref. CIR-ECL-2015-01). The study investigated patients who were treated in the university dental clinic of the International University of Catalonia and who suffered at least one implant failure between January 2011 and December 2018.

Inclusion and Exclusion Criteria

The inclusion criteria were patients presenting at least one failed implant. Due to the lack of complete computerized information, only data of failed implants could be manually retrieved from patients' records. Implants that met any of the following criteria were considered

failures: pain on function, mobility, radiographic bone loss corresponding to more than half the length of the implant, uncontrolled exudate, and the implant no longer being in the mouth. To standardize the inclusion criteria, implant failure was defined as an "implant that did not remain functional in the oral cavity." Patients with an incomplete or incomprehensible data file were excluded from the study.

Surgical Treatment

Partially or totally edentulous patients attending the university dental clinic in need of dental implant-based restorative rehabilitation were seen by dental students from the Department of Oral Surgery and Periodontics, in conjunction with prosthodontics students. The dental students performed an exhaustive clinical and radiologic examination to offer the best treatment plan for the patients. After signing the informed consent, the surgical procedure was performed by postgraduate students. All interventions were conducted under direct supervision by experienced oral surgeons or periodontists. Implant therapy alone or in conjunction with any kind of bone/soft tissue augmentation procedure were included. The implants were restored by the prosthodontics students either immediately or through a delayed approach, depending on the case planning. At the time of prosthesis delivery, all patients were instructed on good oral hygiene and were monitored regularly through check-up visits.

Data Extraction

Data were extracted by two independent reviewers (A.L. and L.I.) from patients who suffered at least one implant failure between September 2011 and July 2018. Given that implant survival was the primary outcome, different risk indicators^{13,21} were analyzed as risk factors for implant loss. Data extracted were as follows:

- **Demographic data:** Patient sex and age. Three age groups were established: young patients (< 40 years of age at the time of surgery), middle-aged patients (between 40 and 65 years), and elderly patients (> 65 years).¹³
- **Patient health data:** Systemic pathologies, history of periodontal disease, and smoking status.
- **Implant data:** Implant brand and location, implants placed in pristine versus augmented sites, and time of placement (immediate/delayed).

Regarding dental implant brand, different implant systems were used in the university dental clinic during the investigated period, particularly six implant brands, which were included in this study: Astra Tech, Biomet 3i, MIS (MIS Implants Technologies), Nobel Biocare, Straumann (Institut Straumann), and Klockner

Table 1 Implant Macrodesign and Microdesign Characteristics: Implant Surface Roughness (S_a value)

	Astra Tech	Biomet 3i	MIS	Nobel Biocare	Straumann	Klockner
Implant design	Tapered/parallel	Tapered	Tapered	Tapered	Tapered/parallel	Tapered/parallel
Implant surface	(Astra Tech) OsseoSpeed	(Biomet 3i) Osseotite	(MIS implants) SLA	(Nobel Biocare) TiUnite	(Straumann) SLA/SLActive	(Klockner, Spain) Shot blasting
Surface treatment	Grit blasted + etched	Etched	Sandblasted + etched	Electrochemically oxidized	Grit blasted + etched/grit blasted	Grit blasted + etched
Degree of roughness	Moderately rough	Minimally rough	Moderately rough	Moderately rough	Moderately rough	Moderately rough
S_a value	1.4 μm	0.68 μm	1.6 μm	1.1 μm	1.78/1.75 μm	1.6 μm

(Klockner Implant System). These implants are different not only in their macrodesign but also in their microdesign. Table 1 describes the geometry and implant surface modifications of each implant brand used in this study. The majority of implant surfaces are modified by sandblasting, grit blasting, acid-etching, or a combination (Astra Tech, Biomet 3i, MIS, Straumann, and Klockner), or chemically oxidized (Nobel Biocare).²² When evaluating the microtopography, S_a is a 3D parameter that describes the surface roughness. Different groups have been classified depending on the S_a values: smooth ($S_a < 0.5 \mu\text{m}$), minimally rough ($S_a = 0.5$ to $1 \mu\text{m}$), moderately rough ($S_a = 1.0$ to $2.0 \mu\text{m}$), and rough surfaces ($S_a > 2.0 \mu\text{m}$).²³

When analyzing implant position, two groups were established including a combination of those: arch (maxilla/mandible) and sector (anterior/posterior), with anterior from canine to canine and posterior from premolar to molar.²⁴

Statistical Analysis

The present study distinguished two levels of analysis: Sex and age were studied at the patient level, while age, implant brand and position, bone augmentation procedures, time of placement, smoking, and periodontal disease were studied at the implant level.

The descriptive statistics comprised absolute and relative frequencies (sex and implant brand and position) and mean, standard deviation, range, and median (age).

Inferential analysis at both the patient and implant levels was based on binary logistic regression models to evaluate the association between implant failure and independent factors. The results were presented as the nonadjusted odds ratio (OR) with the corresponding 95% confidence interval (95% CI). In order to achieve an adjusted OR, multivariable logistic regression models were performed. The level of significance was set at 5% ($\alpha = .05$).

RESULTS

The cohort study included 1,510 patients who received a total of 4,842 dental implants over a 7-year period (2011 to 2018). The sample consisted of 790 women (52.3%) and 720 men (47.7%), with a mean age of 58.1 ± 12.5 years (range: 18 to 90 years). Overall, 72.3% of the patients referred were systemically healthy. Most patients were nonsmokers ($n = 1,256$) representing 83.2% of the total population. It was observed that 48.2% of patients, with a total of 2,135 implants, had a previous history of chronic periodontal disease, while 51.8% of patients with 2,707 implants were periodontally healthy at the time of implant placement (Table 2).

The implants were distributed as follows: Most of the participants (30.8%; $n = 465$ patients) received one implant, 24.8% ($n = 374$) received two implants, 12.3% ($n = 186$) received three implants, 10.5% ($n = 159$) received four implants, and 21.6% ($n = 326$) received 5 to 18 implants. A mean of 3.21 implants were placed per patient.

The majority of implants were placed in the posterior area (78.2%) compared with the anterior zone (21.8%), while implant placement between the maxilla and mandible was more balanced (55.5% vs 44.5%, respectively). The distribution of the implants was as follows: 15.6% anterior maxilla, 39.9% posterior maxilla, 6.2% anterior mandible, and 38.3% posterior mandible. In relation to implant characteristics, 67.4% of implants were placed in pristine bone, while 32.6% of implants required additional bone augmentation procedures. Regarding the time of placement, the most frequently used option was delayed implant placement (81.8%) in comparison with immediate placement (18.2%; Table 2).

Descriptive Analysis

At the patient level, 163 of 1,510 patients had at least one implant failure, representing 10.8% of the total. The majority of patients presented a single failed implant

Table 2 General Patient and Implant Characteristics of the Sample

	N (%)
Patient characteristics	
Sex	
Male	720 (47.7)
Female	790 (52.3)
Systemic pathologies	
No	1,092 (72.3)
Yes	418 (27.7)
Smoking status	
Nonsmoker	1,256 (83.2)
Smoker	254 (16.8)
Periodontal disease	
No	782 (51.8)
Yes	728 (48.2)
Implant characteristics	
Position	
Anterior maxilla	755 (15.6)
Posterior maxilla	1,934 (39.9)
Anterior mandible	299 (6.2)
Posterior mandible	1,854 (38.3)
Bone graft	
No	3,263 (67.4)
Yes	1,579 (32.6)
Time placement	
Immediate	882 (18.2)
Delayed	3,960 (81.8)

($n = 112$, 7.4%), while only one patient presented the maximum number of failed implants ($n = 8$). At the implant level, 237 implants failed (4.9%) out of 4,842 implants placed, representing a cumulative survival rate of 95.1%.

Risk Indicators

Considering sex as a risk factor, 91 out of 720 men presented implant failure (12.6%), while 72 out of 790 women suffered implant loss (9.1%; $P = .028$). The binary logistic model showed that women had a significantly lower implant failure rate than men ($OR = 0.69$; Table 3).

When analyzing age, the youngest population (< 40 years) received 7.4% of the total implants, middle-aged patients (40 to 65 years) received 61.3% of the total implants, and the oldest group (> 65 years of age) received 31.1% of the total implants. Analyzing the association among the three age groups, the binary analyses showed that patients older than 40 years had a 4 to 5 times higher risk of implant failure than the youngest group. Nonetheless, it can be speculated that older patients have a higher number of implants placed, and the same happens with male patients compared to female patients. To avoid any confounding

factors, multiple regression analyses were performed, and the results demonstrated that the greater the number of implants, the greater risk of implant failure, with $OR = 1.30$ for each additional implant. The multiple regression analysis showed that, for the same number of implants per patient, variables such as age and sex were not associated with higher implant failure rates (Table 4). Therefore, the number of implants is the main cause of implant failure. Likewise, at the implant level, binary analyses showed that the association between age and implant failure was similar to that observed at the patient level. A single implant had a higher implant failure rate when the patient became older, accepting the assumption that older patients had a greater number of implants. However, when the number of implants was the same for each patient, age did not affect the implant failure rate (Table 5).

Taking into account the implant position, a tendency toward higher failure rates was observed in implants placed in anterior areas compared with posterior zones ($OR = 1.35$, $P = .071$; Table 5). Furthermore, considering the combination of arch-sector, multivariable analyses showed that a tendency toward increased implant loss in the anterior maxilla was evident (Table 6). A statistically significant reduction in failure rates was observed in the posterior maxilla ($OR = 0.66$, $P = .038$) and in the posterior mandible ($OR = 0.64$, $P = .037$; Table 6). Considering bone augmentation as a risk factor, the cumulative failure rate for implants placed in grafted sites was 6.4%, accounting for a total of 101 implant failures, whereas 4.2% of implants placed in pristine bone failed ($n = 136$). No statistically significant differences were obtained between placing implants in pristine bone or grafted sites. Therefore, bone augmentation procedures were not associated with higher implant failure rates ($P < .05$).

Regarding the time of implant placement, there were no statistically significant differences in the survival rate when comparing immediate and delayed implant placement (6.1% vs 4.6%, $P < .05$).

Considering smoking as a risk factor, 1,256 non-smoker patients with 3,860 implants had 182 implant failures, corresponding to a 4.7% implant failure rate. Contrarily, 254 smokers with 982 implants suffered 55 failures (5.6% failure rate). When considering history of periodontal disease, 124 implants failed in patients with chronic periodontal disease, accounting for an implant failure rate of 5.8%. Contrarily, periodontally healthy patients suffered 113 implant failures, which corresponds to 4.2% of failures. No statistically significant differences were found in failure rates among smokers and periodontally compromised patients ($P < .05$).

Finally, in relation to dental implant brand, MIS implants were regarded as the reference brand, as they represented more than 50% of the total implants placed.

Table 3 Binary Regression Analysis: Findings (Patient-Level Analysis) of Implant Failure According to Age and Sex

	Patient status		OR	95% CI	P value
	No failure	Failure			
Patients (N)	1,347	163			
Age (y)	57.8 ± 12.7	61.2 ± 10.2	1.02	1.01–1.04	.001**
Age group	109 (97.3)	3 (2.7)			.031*
15–39 y	822 (88.8)	104 (11.2)	1	1.43–14.7	
40–65 y	416 (88.1)	56 (11.9)	4.60	1.50–5.9	.010*
> 65 y			4.89		.008**
Sex					
Male	629 (87.4)	91 (12.6)	1		
Female	718 (90.9)	72 (9.1)	0.69	0.50–0.96	.028*

* $P < .05$; ** $P < .01$; *** $P < .001$.**Table 4 Adjusted Multiple Regression Analysis: Findings (Patient-Level Analysis) of Implant Failure According to Age and Sex**

	Patient status		OR	95% CI	P value
	No failure	Failure			
Patients (N)	1,347	163			
Age (y)	57.8 ± 12.7	61.2 ± 10.2	1.01	0.99–1.03	.196
Sex					
Male	629 (87.4)	91 (12.6)	1		
Female	718 (90.9)	72 (9.1)	0.80	0.57–1.14	.216
Implants in mouth (N)	2.91 ± 2.35	5.68 ± 3.90	1.30	1.24–1.37	< .001***

* $P < .05$; ** $P < .01$; *** $P < .001$.**Table 5 Binary Regression Analysis, Non-adjusted OR, and 95% CI: Findings (Implant-Level Analysis) of Implant Failure According to Age, Sex, and Implant Position**

	Failure		OR	95% CI	P value
	No	Yes			
Implants (N)	4,605	237			
Age (y)	60.3 ± 11.4	62.4 ± 9.9	1.02	1.00–1.03	.015*
Age group					.071
15–39 y	201 (98.5)	3 (1.5)	1		
40–65 y	2,799 (95.2)	141 (4.8)	3.38	1.07–10.7	.038*
> 65 y	1,605 (94.5)	93 (5.5)	3.88	1.21–12.5	.023*
Sex					
Male	2,339 (94.5)	135 (5.5)	1		
Female	2,266 (95.7)	102 (4.3)	0.78	0.55–1.10	.159
Dental arch					
Mandible	2,060 (95.7)	93 (4.3)	1		
Maxilla	2,543 (94.6)	144 (5.4)	1.25	0.92–1.71	.153
Region					
Posterior	3,615 (95.4)	173 (4.6)	1		
Anterior	990 (93.9)	64 (6.1)	1.35	0.97–1.87	.071

* $P < .05$; ** $P < .01$; *** $P < .001$.

The results showed that Nobel Biocare and Straumann implants significantly reduced the risk of implant failure (OR = 0.37, $P = .021$ and OR = 0.53, $P = .024$, respectively) compared with MIS implants. In contrast, the failure

rates did not differ significantly among Klockner (2.8%), MIS (5.4%), Biomet 3i (7.1%), and Astra Tech brands (8.4%; $P < .05$; Table 6). Overall, all implant brands presented high implant survival rates above 91%.

Table 6 Multiple Regression Analysis, Adjusted OR, and 95% CI: Findings (Implant-Level Analysis) of Implant Failure According to Age, Sex, Implant Position, and Implant System

	Failure		OR	95% CI	P value
	No	Yes			
Implants (N)	4,605	237			
Age (y)	60.3 ± 11.4	62.4 ± 9.9	1.02	1.00–1.03	.015*
Sex					
Male	2,339 (94.5)	135 (5.5)	1		
Female	2,266 (95.7)	102 (4.3)	0.86	0.61–1.22	.396
Position					.119
Anterior maxilla	702 (93.0)	53 (7.0)	1		
Posterior maxilla	1,843 (95.3)	91 (4.7)	0.66	0.44–0.98	.038*
Anterior mandible	288 (96.3)	11 (3.7)	0.51	0.24–1.12	.093
Posterior mandible	1,772 (95.6)	82 (4.4)	0.64	0.42–0.97	.037*
Implant brand					.003**
MIS	2,438 (94.6)	138 (5.4)	1		
Astra Tech	284 (91.6)	26 (8.4)	1.62	0.89–2.94	.101
Klockner	280 (97.2)	8 (2.8)	0.51	0.24–1.30	.175
Biomet 3i	380 (92.9)	29 (7.1)	1.35	0.79–2.19	.290
Nobel Biocare	241 (98.0)	5 (2.0)	0.37	0.14–0.85	.021*
Straumann	938 (97.1)	28 (2.9)	0.53	0.32–0.92	.024*

* $P < .05$; ** $P < .01$; *** $P < .001$.

DISCUSSION

The present retrospective study documented 163 implant failures in 237 patients over a 7-year period, resulting in a cumulative survival rate of 95.1% and 89.2% at the implant and patient levels, respectively. A number of publications reported implant survival rates consistent with the results obtained in the present study.^{6,11–13,25} A clinical study by Chrcanovic et al recorded a 93.6% implant survival rate based on 10,096 implants.²⁵ In a more recent retrospective study involving an even greater sample size (30,959 implants placed by experienced surgeons), the survival rates were 98.7% and 98.0% at the implant and patient levels, respectively.¹³ On the other hand, a systematic review by Howe et al revealed a survival rate of 96.4% (95% CI: 95.2% to 97.5%) after 10 years of follow-up using contemporary implant systems.¹¹ The literature shows that implant survival rates have progressively increased over the last decade.²⁶ The adoption of improvements in both macro- and micro-design, and the introduction of modern surgical techniques, have significantly increased implant survival rates in the last few decades. Most implants investigated in this study had a moderately rough surface (roughness of 1 to 2 μm), which provided an optimal degree of roughness to promote osseointegration²⁷; however, long-term success could be compromised due to the higher affinity to bacterial adhesion and consequently higher risk of peri-implantitis. No association could be found in this study between the implant design and the failure rate. This is in agreement with several publications where no optimal implant surface has been identified yet and

highlights clinical circumstances and clinicians' skills on implant selection criteria.^{5,27}

Regarding operator experience, and contrary to what would be expected, postgraduate students obtained implant survival rates similar to those of more experienced surgeons. There is some controversy regarding the association between implant survival and surgeon experience. While some authors^{3,14,28} concluded that the quality of implant treatment and clinician experience were directly correlated to implant survival—favoring implants placed by faculty members—others have found the survival rates of implants placed by surgeons in training to be comparable to the rates reported in the literature.^{17,29,30} Prasad et al reported a 96.4% implant survival rate for predoctorate operators placing 1,918 implants in 1,091 patients.¹² Moreover, data from a meta-analysis based on four retrospective studies concluded that surgical experience did not significantly affect implant survival, considering experienced professionals as specialists, with an OR of 1.24 (95% CI: 0.62 to 2.48).³⁰ This study reflected the high predictability of dental implants even when placed by postgraduate students,^{12,30} and supervision by experienced surgeons and extensive treatment planning may explain this high implant survival rate.

The results obtained in the present study suggested that sex affected implant failure rates, with a lower risk of implant loss in women (OR = 0.69). This is in agreement with some clinical studies in which the male sex was associated with a significantly increased failure rate,^{13,19,29,31} including the study carried out by Zupnik et al,²⁹ who found men to have a fourfold higher risk

of implant failure compared with women. Nonetheless, the data found in the literature are not consistent in this regard. A retrospective study involving a longer follow-up period and based on an elderly population was unable to show an influence of sex on implant loss.³²

On the other hand, the question of whether patient age is related to implant failure is controversial. The present study failed to demonstrate a positive relationship between age and implant failure. Hence, age alone did not seem to affect the implant survival rate. It was also suggested that the fact that older patients presented a greater number of implants might increase the probability of higher implant failure rates. In this line, Naert et al reported that increasing the number of placed implants increased the failure risk by 0.14-fold.³³ Some researchers supported that implant therapy in elderly patients does not seem to affect implant survival rate, and that implant treatment represents a successful rehabilitation option for patients > 65 years of age.^{32,34–37} Implants, therefore, can be successfully placed in older adults, but special care is needed to limit factors associated with implant failure.³⁴ Despite this, other studies have reported that older patients (> 65 years) could face a higher risk of implant loss.^{11–13} This phenomenon could be attributed to poorer oral hygiene associated with the elderly population¹³ or decreased bone quality and impaired bone formation associated with older patients, thereby compromising the long-term prognosis of the implant.³⁸

Regarding the location of implants, a marked discrepancy was observed between implants placed in the anterior versus the posterior region, with the latter being the most common implant position (78.2%). Several studies agree that posterior regions are the most frequently restored areas with dental implants.^{1,14,19} Implant location was not found to be a determinant factor for implant failure, though the present study found that the failure rate tended to increase when implants were inserted in the anterior compared with the posterior region (OR = 1.35). Contradictory findings in relation to failure risk between the maxilla and mandible have been found in the literature.^{14,18,39} Overall, in this study, the arch sector has been observed to be more determinant, with higher failure rates in the anterior maxilla. This could be attributed to the thinner ridge in this zone and the increased number of immediate implants and bone augmentation procedures associated with this region. It has been widely reported that dental implants combined with simultaneous guided bone regeneration are a predictable treatment option,^{9,24} but surgeon inexperience together with the increased technical demands of the procedure might have played a role in greater implant loss in this region. Conversely, several publications agree that the anterior mandibular region is more prone to implant failure, and this has been attributed to the narrow ridge shape and type I

bone density.^{6,13} In this regard, Lin et al reported that implants placed in the anterior mandible are two times more likely to suffer implant loss than those in the posterior mandibular region.¹³ There is an important debate as to whether implant location is a risk factor for implant loss and regarding the most unfavorable position for implant placement.

This study failed to demonstrate any association between implant failure and bone augmentation procedures. This finding is in accordance with several studies reporting high implant survival rates in regenerated bone.^{9,24,39,40} Tran et al, after evaluating nearly 3,000 dental implants over a 15-year period, found that there was no difference in dental implant survival rates when implants were placed in native bone or grafted sites.²⁴ Nevertheless, whether implant failure is associated with bone grafting procedures is still controversial. Other researchers concluded that implants placed in augmented sites were associated with a higher risk for implant loss compared with nonregenerated sites.^{13,31} The authors justify these results by the increased difficulty associated with bone augmentation procedures, longer surgical time, and, consequently, greater risk for infection.¹³ Therefore, further evaluation of this association is warranted.

The literature is not conclusive when analyzing timing of implant placement as a risk factor. A systematic review based on 3,049 implants found that the survival rate of delayed implants (98.4%) was significantly greater than immediate implants (95.2%).⁴¹ However, Bassir and colleagues, in a meta-analysis based on 12 studies, revealed that there were no statistically significant differences in implant failure between immediate, early, and delayed implant placement protocols.⁴² The present study was not able to highlight this factor as a risk indicator for implant failure.

Smoking has been commonly described as a risk factor for implant failure.^{21,24,39} Tran et al found that smokers had more than twice the risk of implant loss compared with nonsmokers.²⁴ It is also important to note that the number of cigarettes smoked daily has a direct impact on implant survival. Sánchez-Pérez et al, after classifying individuals as light, moderate, and heavy smokers, found that heavy smokers had more than twice as high a risk of implant failure compared with light or moderate smokers.⁴³ However, contrary to the results of the aforementioned studies, several researchers did not report a clear association.^{44,45} The present study did not find any association between smoking and implant loss. Also, a potential limitation of this research was the lack of assessment of the quantity and quality of tobacco intake, which could have affected the implant failure rates.

There is strong evidence supporting the assumption that history of periodontal disease is a risk factor

for implant loss. Several clinical studies and three systematic reviews and meta-analyses revealed that periodontitis was statistically associated with a higher risk of implant failure versus a healthy periodontium^{21,45–48} and agreed that patients with aggressive periodontitis had a higher risk of implant loss compared with those with chronic periodontitis.⁴⁸ Conversely, other studies could not find any association between periodontitis and implant loss. The authors justified this result by the stricter maintenance program that adhered to periodontally compromised patients and concluded that dental implants are a viable and safe option.^{49,50} In line with these publications, this research did not find any association between a history of periodontal disease and implant failure. A possible explanation for this result is that all patients from the dental clinic were periodontally stable when the implant therapy was performed, with a Plaque Index (PI) < 20%.

Comparing six frequently used implant brands, Nobel Biocare and Straumann implants exhibited significantly lower implant failure rates compared with the other implant brands included in the present study (Klockner, MIS, Biomet 3i, and Astra Tech). This high implant survival rate (> 97%) is consistent with data reported by van Velzen et al in 2015, where the 10-year implant survival rate of 374 Straumann implants was found to be 99.7% and 99.4% at the implant and patient levels, respectively.¹⁰ Due to the short follow-up period of this study, early implant failure was the main cause of implant loss. Increased failure rates and other causes of failure, such as peri-implantitis, would be expected over a longer follow-up. Considering the results reported in the literature, it can be concluded that the survival rate for Straumann implants at the implant and patient levels over the middle to long term is very high (> 95%).^{4,6,10} Few data can be found in the literature regarding implant survival according to different commercial brands, and the published results found no significant differences among the different implant systems.^{11,12} A study assessing the survival and success rates of the same implant brands included in this study (Straumann, Astra Tech, Nobel Biocare, and Biomet 3i) could not find any effect on the clinical and radiographic outcomes when the implant system was evaluated.⁹ Therefore, even with the higher implant survival rates of Nobel Biocare and Straumann implants obtained in this study, all implant systems appear to be highly successful.

This study has several limitations inherent to its retrospective design: the lack or inaccuracy of data due to incomplete records, which complicated the statistical analysis; the individual variability among the operators; the use of different implant brands; the heterogeneity of the treatments; and finally, the short follow-up periods of some patients. In this regard, a

longer follow-up could lead to an increased failure rate, with peri-implantitis being one of the most common causes of late implant loss.^{13,49} The data on systemic conditions, type of reconstruction, prosthetic loading, and peri-implant status could not be retrieved from patients' files; hence, these variables were not analyzed. This was another limitation of the present study, which could lead to the inaccuracy of the outcomes, but the large population compensated for this lack of information. Also, another limitation of this study was that only survival rates were obtained due to the impossibility of gathering the necessary data to report the success rates.

CONCLUSIONS

Implant failure rates of dental implants placed over a 7-year period by postgraduate students supervised by experienced professionals in a university setting showed overall cumulative failure rates of 4.9% and 10.8% at the implant and patient levels, respectively. The results obtained show that the male sex and implants placed in the anterior mandible may pose a higher risk of implant failure, while the Nobel Biocare and Straumann implant brands seem to improve the implant survival rate compared with other common implant brands. The results of this study should be interpreted with caution due to the limitations inherent in retrospective studies.

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