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Long-Term Survival of Dental Implants with Different Prosthetic Loading Times in Healthy Patients: A 5-Year Retrospective Clinical Study

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Abstract

Purpose: To compare survival rates among dental implants restored with immediate, early, and conventional loading protocols, also comparing between maxillary and mandibular implants, and to evaluate the influence of implant length and diameter and the type of prosthesis on treatment outcomes.
Materials and Methods: This retrospective cohort study initially included all 52 patients receiving dental implants between July 2006 and February 2008 at a private oral surgery clinic in Granada (Southern Spain). Clinical and radiographic examinations were performed, including periapical or panoramic radiographs, and incidences during completion of the restoration were recorded at 1 week, 3 months, 6 months, and at 1, 2, 3, 4, and 5 years. After a 5-year follow-up, 1 patient had died, 3 were lost to follow-up, and 6 required grafting before implant placement; therefore, the final study sample comprised 42 patients with 164 implants.
Results: Variables associated with the survival/failure of the restoration were: number of implants (higher failure rate with fewer implants), bone type (higher failure rate in type III or IV bone), and type of prosthesis (higher failure rate with single crowns). No significant association was found in univariate or multivariate analyses between survival rate and the loading protocol, implant length or diameter, or maxillary/mandibular location.
Conclusions: Immediate occlusal loading, immediate provisionalization without occlusal loading, and early loading are viable treatment options with similar survival rates to those obtained with conventional loading. Bone quality and number of implants per patient were the most influential factors.

Over more than 100 years of root-form dental implant development, prosthetic loading times have varied according to implant design. In 1913, Greenfield[1] introduced a "latticed" implant made of platinum that was loaded after 4 to 6 weeks of transmucosal healing. This would be considered early loading by present-day standards.[2] In the 1970s, Brånemark et al[3] used a two-stage surgical technique with conventional loading times of 3 to 6 months, depending on bone density and volume. This was based on concerns that any implant micromotion could result in fibrous tissue encapsulation and clinical failure of the implant.[4-6] Later research showed that implant micromotion was influenced by numerous clinical factors, such as bone density of the patient,[7] surgical technique,[8] insertion torque,[9,10] macro design,[8,10,11] and implant surface texture.[9-11] It was also found that micromotion exceeding 50 to 150 μm could have deleterious effects.[12] One outcome of the research by Brånemark et al[3] was that their highly successful two-stage surgical protocol with delayed loading became axiomatic for root-form implants during the 1980s and 1990s.

With continuing advances in implant design and surgical technique, some histological and clinical studies reported osseointegration rates in early or immediately loaded implants with primary stability that were comparable or superior to those obtained when loaded conventionally.[2,4,13] Immediate loading was defined as an implant put in function within 1 week after its placement and early loading as those implants put in function between 1 week and 2 months after their placement.[2] There has been renewed interest in immediate and early implant loading to reduce surgical trauma, shorten treatment time, and satisfy patient demands for immediate esthetics and function.[2,4,14-16]

This study reports on a retrospective evaluation of the influence of prosthetic loading times and other clinical variables on the survival of one-stage dental implants with a transmucosal abutment. The study objectives were to compare survival rates among implants restored with immediate interim prostheses with or without occlusal contact, early, and conventionally loaded implants, also comparing between maxillary and mandibular implants, and to evaluate the influence of implant length and diameter, and type of prosthesis on treatment outcomes. The null hypothesis was that cumulative implant survival rates would not significantly differ according to the loading time (immediate, early, or conventional).

Materials and methods

Patient selection

A nonrandomized, uncontrolled retrospective study was conducted to determine the outcome of threaded endosseous implants with microtextured surfaces (SwissPlus®; Zimmer Dental Inc., Carlsbad, CA) placed in a private oral surgery clinic in Granada, Spain. Chart reviews were conducted for all patients who presented for treatment of one or more missing and/or unrestorable teeth between July 2006 and February 2008; patients were followed up for ≥5 years posttreatment. General exclusion criteria for implant placement included routine use of antibiotics or corticosteroids for general diseases, receipt of radiotherapy and/or chemotherapy, history of renal failure, and the presence of leukocyte dysfunction/deficiencies, bleeding disorders, bone or endocrine disorders, immunodeficiency disorders, severe bruxism, physical handicaps capable of interfering with oral hygiene maintenance, and heavy smoking (>10 cigs/day). Patients who required bone grafting before implant placement were also excluded from the present study, which only included implants placed in native bone; the aim was to avoid introducing a confounding variable that might influence the true survival of the implants.

All patients underwent preliminary evaluations that included clinical and radiographic examinations, a review of their medical and dental histories, and an assessment of their oral hygiene and capability to commit to oral hygiene and long-term follow-up. A diagnostic workup was performed, using cone beam computed tomography (CBCT), study models, and photographs, to evaluate the volume and location of available bone in relation to the prosthodontic needs of the patient. Based on these data, study casts were fabricated and mounted on semiadjustable articulators, using a facebow transfer, and vertical dimensions were registered to determine the jaw relationships, available freeway space or interocclusal distance, proposed implant position(s), crown-implant ratio, and potential complications. Treatment plans were developed to meet the functional and esthetic needs of each patient and the desires expressed by the patients. The diagnostic casts were used to create wax patterns and for the fabrication of surgical templates to guide implant placement relative to the planned prosthesis. Treatment plans and alternative options were discussed with the patients, who all signed their informed consent to participation in the study, which was approved by the ethical committee of the University of Granada (reference no. 621)

Table 1 Implant loading times

Designated loading time	Required implant insertion torque	Prosthesis delivery time
Immediate loading	≥45 Ncm	Within 1 week after implant placement
Immediate loading without occlusal contact	≥45 Ncm	Within 1 week after implant placement
Early loading	30-45 Ncm	Between 1 week and 2 months after implant placement
Delayed loading	<30 Ncm	After 2 months of implant placement

Surgical procedures

Patients were instructed to rinse with chlorhexidine digluconate for 2 minutes before the surgery and daily for 15 days postoperative. Administration of amoxicillin and clavulanic acid (Augmentine; GSK, Madrid, Spain) as antimicrobial prophylaxis began at 2 hours before surgery and continued for 7 days. Patients were anesthetized by local infiltration in the maxilla or by inferior alveolar block in the mandible. In cases with unrestorable dentitions, teeth were extracted using a gentle avulsion technique to minimize trauma to the surrounding tissues, and the extraction sockets were thoroughly debrided to eliminate granulation tissue. The space required for the restoration was determined by using the study model and the cast mounted in the articulator. Surgical incisions and flap elevations were conservatively performed to favor preservation of periosteal vascular supply. Osteotomies were prepared with the aid of a surgical template using a series of internally irrigated surgical drills with graduated diameters. During preparation of each implant site, bone type was assessed based on tactile feedback and radiographic density (CBCT) and recorded in the patient's records according to the Lekholm and Zarb[17] classification system. Implants (SwissPlus drills; Zimmer Dental Inc.) were manually threaded into the osteotomies using a calibrated torque gauge (N.V. Tonichi Europe S.A., Boortmeerbeek, Belgium), and the insertion torque values were included in the patient's records. All implants were placed by a single dental surgeon (MV-C) in accordance with the manufacturer's instructions. In patients where implants were placed into fresh extraction sites, coronal gaps greater than 1 mm were grafted with autogenous bone harvested from implant drilling and mixed with a xenograft (Bio-oss; Geistlich AG, Wolhusen, Switzerland), which was covered with a resorbable barrier membrane (Bio-gide, Geistlich AG).

Prosthodontic procedures

Implant loading protocols were: immediate occlusal loading or immediate loading without occlusal contact (within 1 week of placement), early loading (between 1 week and 2 months after placement), or conventional loading (2 months after placement).[2,18] The decision was made by consensus between the dental surgeon and the prosthodontist and was based on

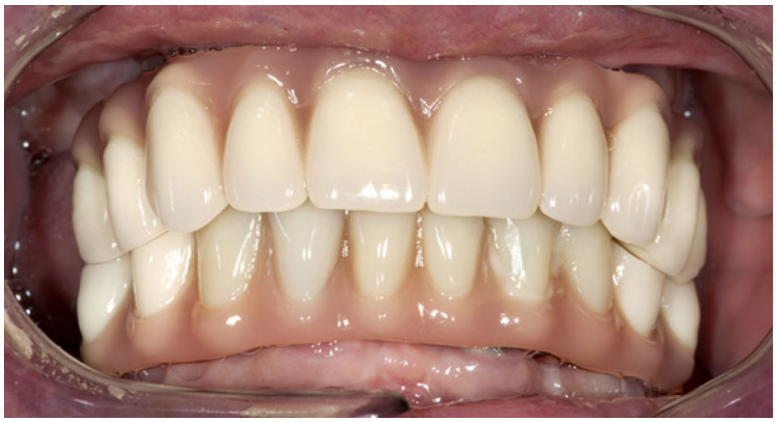

Figure 1 Complete fixed implant restoration immediately loaded with full contact in centric occlusion.

the implant insertion torque value, following the criteria proposed by Esposito et al.[2] The loading times are summarized in Table 1. All prostheses were placed by the same clinician (MMJ). Only edentulous patients were treated with immediate occlusal loading (Fig 1); in these patients, a full-arch impression was made immediately after implant placement with fluid and heavy addition silicon (Elite HD+; Zhermack, Rome, Italy) in one step, using a prefabricated tray to manufacture a screw-retained prosthesis. The impression was made by employing the implant's transfer component. The technician then used the impression to fabricate the prosthesis for placement within 1 week after the implant surgery.

The decision to use overdentures was made before the implant placement and was based on economic criteria, the expectations of the patient, the bone quantity/quality (CBCT study), and the loss of support tissues. Ball abutments were used as retentive devices for the overdentures (Zimmer Dental Inc.). Maxillary and mandibular baseplates and occlusion rims were made and used to record the maxillomandibular jaw relationship. The maxillary and mandibular casts were mounted, denture teeth were set (Major Dent, Moncalieri, Italy), and the esthetics, phonetics, and occlusion were evaluated and adjusted as necessary. A single technician processed all of the prostheses using heat-polymerized acrylic resin (Meliodent; Heraeus Kulzer Ltd, Newbury, Germany).

A healing pillar was threaded into the implant until placement of the prosthesis, and the soft tissues were sutured around it. Sutures were removed after 7 days of soft-tissue healing. The patients wore no type of prosthesis during the first week to permit correct soft tissue healing. Then, prostheses were placed in patients due to undergo immediate occlusal loading or immediate provisionalization without occlusion. No interim fixed prostheses were made for early-loaded or conventionally loaded implants, but complete or partial removable prostheses were made or adapted for these patients, leaving a gap over the implant site to avoid any minimal contact and placing a soft liner to allow the patients to use these prostheses during the healing period.

Complete fixed implant restorations and overdentures were in full contact in centric occlusion. Ball abutments for overdentures were fixed by the technician to achieve a perfect contact between the ball in the implant and the retentive device in the overdenture. Single crowns and single partial dentures on implants restored with immediate interim prostheses were 1 or 2 mm shorter to avoid occlusion (Fig 2), serving only to maintain the esthetic appearance and allow correct soft tissue growth.[19]

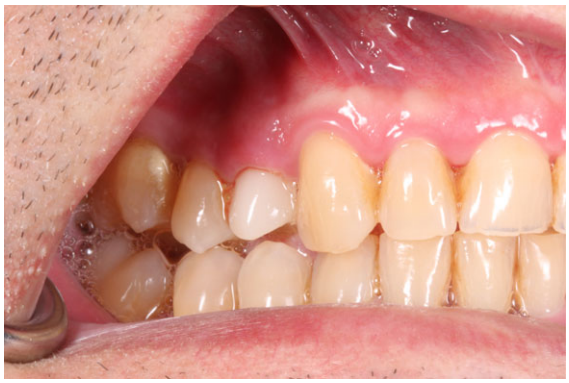

Figure 2 Immediate provisional implant restoration replacing the upper right first premolar; it is 2 mm shorter to avoid occlusion.

Follow-up and survival criteria

Adverse events were recorded, and patients were followed for at least 5 years. Patients were seen immediately after any incidence was reported and were all followed up at 1 week and at 3, 6, and 12 months after implant placement and then annually for at least 4 years. Figure 3 depicts the timing of each implant failure. The criteria for implant survival were the absence of detectable implant mobility, clinical symptoms (e.g., pain, sensation of a foreign body, or dysesthesia), radiolucent areas around the implants, and recurrent infection with suppuration at the implant periphery, as defined by Buser et al.[20]

Data collection

Data were gathered on demographic characteristics (patient age and sex) and clinical variables, including number, length, diameter, and location of implants; bone density at the implant site; type of prosthetic rehabilitation (single crown, fixed partial denture, or overdenture); and loading time (immediate occlusal

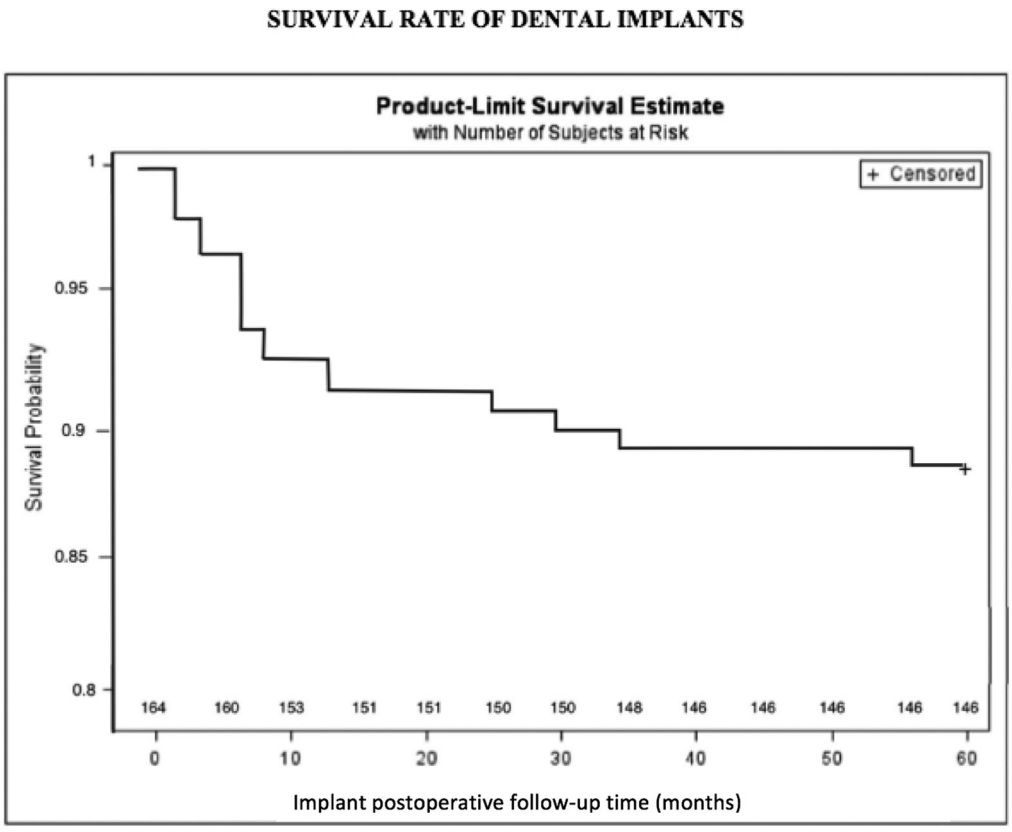

Figure 3 Survival rate of dental implants included in this study.

loading or immediate loading without occlusal contact, early, or conventional loading). All data were entered into a spreadsheet (Excel, Microsoft Corp., Redmond, WA) on a personal computer by the same researcher.

Statistical analysis

Software (SPSS-Windows 17.0; IBM Inc., Chicago, IL) was used for patient-based analyses, and SUDAAN 7.0 (RTI; Research Triangle Park, NC) for implant-based analyses was employed to adjust standard errors and *p*-values for clustering of multiple implants per patients. The implant survival rate was determined by using the Kaplan-Meier estimator to plot the survival curve. Binary logistic regression analyses (univariate and multivariate analyses) were performed, with implant failure as dependent variable and patient and implant characteristics as predictor variables, recording odds ratios with confidence intervals and *p* values. Finally, the variables were included in a backward stepwise procedure ($p < 0.05$ to enter and $p > 0.10$ to exit).

Results

The initial database comprised 52 patients treated between July 2006 and February 2008. Ten patients were subsequently excluded: three were lost to the clinical follow-up, six required grafting before implant placement due to insufficient bone volume, and one died. The final study group comprised 42 patients (21 males, 21 females) treated with 164 implants that were clinically monitored for 5 or more years. The distribution of patients and implants are summarized in Table 2. The bone was type II in 42.68%, type III in 37.19%, type I in 10.36%, and type IV in 9.75%. Implants were placed in the maxilla in 53.04% of patients and in the mandible in 46.95%. The type of edentulism was classified as complete (6.09%), presence of teeth in antagonist arch (13.41%), presence of teeth in same arch not adjacent to the implant (28.04%), and presence of teeth adjacent to the implant (52.43%). Implants were immediately loaded in 20.12% of cases, early loaded in 27.43% of cases, conventionally loaded in 31.70% of cases, and immediately provisionally restored without occlusal contact in 20.73% of cases.

At total of 18 implants failed (10.97%): 6 for mobility, 2 for irresolvable pain, 9 for recurrent infections, and 1 for periimplant radiolucency, while 146 implants (89.03%) survived up to the last available follow-up time. The majority of failures ($n = 13$) took place during the first 12 months after implant placement.

In both univariate and multivariate analyses, the variables associated with the survival/failure of the implants were the number of implants (higher failure rate with fewer implants) and the bone type (higher failure rate in type III or IV bone). There was a tendency for a larger number of failures in implants restored with single crowns, although this difference was not statistically significant in multivariate analysis. No significant

Table 2 Patient demographics and implant distribution

Variable	Description	n (%)
Patient sex	Male	21 (50)
	Female	21 (50)
Patient age (years)	26-50	23 (54.76)
	51–72	19 (45.24)
	Mean ± SD	47.5 ± 11.2
No. of implants per patient	1-2	20 (47.61)
	3-5	11 (26.19)
	6-12	11 (26.19)
	Mean ± SD	3.79 ± 2.63
Implant length	10 mm	50 (30.48)
	12 mm	70 (42.68)
	14 mm	44 (26.82)
Implant diameter	3.7 mm	32 (19.51)
	4.1 mm	110 (67.07)
	4.8 mm	22 (13.41)
Bone quality[17]	D1	17 (10.36)
	D2	70 (42.68)
	D3	61 (37.19)
	D4	16 (9.75)
Implant placement site	Maxilla	87 (53.04)
	Mandible	77 (46.95)
Type of prosthesis	Single tooth	22 (52.38)
	Fixed partial denture	11 (26.19)
	Full-arch denture	9 (21.42)
Edentulism type	Complete	10 (6.09)
	Presence of teeth in antagonist arch	22 (13.41)
	Presence of teeth in the same arch	46 (28.04)
	Presence of teeth in the same arch adjacent to the implant	86 (52.43)
Timing of definitive prosthetic loading	Immediate loading without occlusal contact	34 (20.73)
	Immediate loading (≤ 1 week)	33 (20.12)
	Early loading (1week-2 months)	45 (27.43)
	Delayed loading (>2 months)	52 (31.70)

association was found (in univariate or multivariate analyses) between survival and loading time, implant length or diameter, or maxillary/mandibular location (Table 3).

Discussion

In this study, the timing of implant loading had no significant influence on the survival of the implants. There is an increasing trend for survival rates to be similar between immediate and conventional loading in both fixed prostheses and overdentures.[21-23] It appears important to select patients without severe bruxism who are not heavy smokers, as in the present study. There is a consensus on the types of implant that favor immediate loading, including those that can be screwed, those with a roughened (sandblasted and acid-etched) surface[24] and those of more conical design. If a rigorous protocol is followed, similar outcomes to those obtained with delayed loading can be achieved under these conditions.[2,25-27] In agreement with previous studies, both immediate and early loading proved to be viable procedures in the present study, achieving similar survival rates to those obtained with conventional loading.[28] Our results are also consistent with findings by Degidi et al, who reported that immediate functional and nonfunctional loading (immediate provisionalization) were satisfactory treatments in selected cases. Immediate provisionalization combines the advantages of one-stage implantation with those of immediate loading.[18] Where possible, interim prostheses should remain in place throughout the healing process, allowing adequate healing of the hard and soft tissues in contact with the implants and the prosthesis.[29]

Likewise, no differences in outcome were observed as a function of implant length, perhaps because all implants had a length of ≥10 mm, as recommended by other authors to ensure high survival rates.[31]The greater the implant diameter, the more favorable the load distribution, and a minimum implant diameter of 4 mm has been recommended for an adequate area of contact between implant surface and bone.[27,32] However, in the present study, no difference in outcome was observed as a function of implant diameter, regardless of the timing of the loading, perhaps because the narrowest diameter was 3.7 mm.

Implants in type III and IV bone were more likely to fail in this study, while higher survival rates were achieved in the more dense type I and II bone[33] with superior primary stability. The important influence of bone type on implant outcome is well documented.[24,27] Forces are transmitted though the implant core into cortical bone in type I and II bone and into spongy bone in type III and IV bone. Our high failure rates for implants placed in type III and IV bone suggest that immediate or early loading at these sites should be avoided, especially in the case of single implants without splint. Some authors underlined the importance of preserving the cortical bone during drilling of the implant bed to improve the primary stability.[34]

The length and shape of implants are less critical in cortical bone, which is around tenfold harder than the much more elastic spongy bone,[35] which has a reduced resistance for supporting loading. Finite element analysis has demonstrated that the distribution of forces is more important than the available bone volume in low-density bone.[36]

No significant difference in outcome was found as a function of the mandibular or maxillary localization of the implant, in agreement with Buchs et al[37] and Horiuchi et al[30] In contrast, Hutton et al[38] and Palma-Carrió et al[39] reported a greater risk of failure in the maxilla, attributed to its generally poorer bone quality, with more spongy than cortical bone,[38] compromising the primary stability of the implant for immediate or early loading.

Table 3 Summary of failed implants and results of binary logistic regression[a]

			Implant failures Binary logistic regression analysis[b]			
			Univariate		Multivariate[b]	
Subject and implant variable	N total implants	N failed implants (%)	OR (95% CI)[c]	*P*-value[d]	OR (95% CI)[c]	*P*-value[d]
All implants	164	18 (10.97[e])				
Patient sex				0.377		
Male	80	7 (4.26)	0.61 (9.20-1.88)			
Female	84	11 (6.7)	1.00			
Patient age (years)				0.538		
26 to 50	75	8 (4.87)	0.70 (0.22-2.21)			
51 to 72	89	10 (6.09)	1.0			
Implants per patient (n)				**<0.001**		**<0.001**
1 to 2	25	9 (5.48)	18.20 (3.65-90.65)		41.89 (8.47-207.2)	
3 to 5	48	7 (4.26)	5.88 (1.14-30.17)		3.83 (0.87-16.95)	
6 to 12	91	2 (1.21)	1.00		1.00	
Implant length				0.790		
10 mm	50	5 (3.04)	0.70 (0.18-2.66)			
12 mm	77	7 (4.26)	0.65 (0.18-3.31)			
14 mm	44	6 (3.65)	1.00			
Implant diameter				0.905		
3.7 mm	32	4 (2.43)	0.99 (0.16-6.18)			
4.1 mm	110	11 (6.7)	0.77 (0.18-3.31)			
4.8 mm	22	3 (1.82)	1.00			
Bone quality				**<0.001**		**<0.001**
D1	17	0 (0)	1.00		1.00	
D2	70	3 (1.82)	1.43 (0.16-6.18)		3.54 (0.53-12.03)	
D3	61	9 (5.48)	4.86 (1.17-20.12)		10.60 (2.39-46.97)	
D4	16	6 (3.65)15.67	15.67 (3.75-65.49)		43.47 (9.01-209.7)	
Implant placement site				0.869		
Maxilla	87	10 (6.09)	1.11 (0.33-3.76)			
Mandible	75	8 (4.87)	1.00			
Type of prosthesis				**0.021**		0.16
Single Tooth	22	6 (3.65)	13.42 (1.64-24.73)		32.43 (3.82-53.28)	
Fixed Partial Denture	76	9 (5.48)	3.25 (0.30-8.06)		6.82 (1.31-8.06)	
Overdenture	66	3 (1.82)	1.00		1.00	
Loading time				0.866		
Immediate without occlusal contact	34	4 (2.43)	1.52 (0.36-6.67)			
Immediate (≤ 1 week)	33	3 (1.82)	1.48 (0.34-6.40)			
Early (1 week to 2 months)	45	6 (3.65)	1.29 (0.30-5.51)			
Delayed (>2 months)	52	5 (3.04)	1.00			

[a]Dependent variable: "implant failure;" predictor variables: "patient(s)" and "implant(s)" (n = 164 implants).

[b]Variables included by backward stepwise procedure ($p < 0.05$ to enter and $p > 0.10$ to exit).

[c]OR = odds ratio; CI = confidence interval.

[d]Calculated using the LOGISTIC procedure of SUDAAN, which accounts for clustering of multiple implants per patient.

[e]95%CI = 4.9 to 14.8.

No statistically significant association was found between the type of prosthesis and implant survival in multivariate analysis, although there was a tendency to a higher failure rate with single crowns. Some authors found a higher failure rate for implants placed adjacent to natural versus nonnatural teeth.[39] The majority of implant failures in our study took place within a year of their placement, suggesting the need to be alert to possible risk factors and complications during this period, which could be an aspect to take into account in future research.

Conclusion

Immediate and early loading are viable treatment options, with similar survival rates to those obtained with conventional loading. Bone quality is the most important factor, and higher failure rates were observed in type II and IV bone. Failure rates were also higher with the placement of fewer implants. The diameter and length of implants do not appear to influence outcomes, as long as they are ≥10 mm long and ≥3.7 mm wide.

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