Published in final edited form as:

J Oral Maxillofac Surg. 2008 February ; 66(2): 251–255. doi:10.1016/j.joms.2007.09.012.

Delayed versus Immediate Loading of Implants: Survival Analysis and Risk Factors for Dental Implant Failure

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Abstract

Purpose—The purpose of this study was to estimate one-year implant survival for delayed versus immediately loaded implants and identify risk factors for implant failure.

Materials and Methods—This was a retrospective cohort study, consisting of a sample of subjects who had 1 Bicon® dental implant placed over a 13-year period. The primary predictor variable was method of implant loading: delayed (3 – 6 months after placement) or immediately after insertion. Secondary predictor variables were classified as demographic, anatomic, implant/abutment and reconstructive. The outcome variable was implant failure, defined as removal of the implant and was recorded as months of survival. Descriptive, Kaplan-Meier, and univariate Cox proportional hazards statistics were computed. Univariate associations with $p \leq 0.15$ and biologically relevant variables (e.g. age, gender) were included in a marginal multiple Cox regression model. In the multiple model, a p -value ≤ 0.05 was considered statistically significant.

Results—The study sample consisted of 677 subjects who had 2349 delayed loaded dental implants and 178 patients who had 477 immediate loaded implants. The unadjusted one-year survival estimates for the delayed and immediate loading groups were 95.5% and 90.3%, respectively ($p < 0.01$). In the marginal multiple Cox regression model, immediate loading, current tobacco use, maxillary implants, and shorter implants were associated with failure ($p \leq 0.05$).

Conclusion—In this study, immediately loaded implants were 2.7 times (after adjusting) more likely to fail at one-year compared to delayed loaded implants.

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Introduction

After the placement of dental implants, a 3 – 6 month load-free healing period has been traditionally suggested as the optimal period to ensure successful healing and osseointegration.^{1–3} This recommendation is based on the notion that increased vertical or lateral force upon the implant during the healing phase results in implant motion, aberrant healing and fibrous tissue encapsulation, rather than the bone formation required osseointegration.^{4–7} More recently, however, this clinical suggestion has been challenged. Numerous practitioners now advocate immediate loading of implants (i.e. placing a full occlusal load onto the implant via the prosthesis, within 72 hours after placement).^{8–13} The advantages of immediately loading implants are clear: they allow for shorter treatment times and allow for immediate restoration of function and esthetics. These advantages, however, may be offset by an increased risk of implant failure.

The purposes of the present study were to 1) estimate the one-year implant survival for delayed versus immediately loaded implants and 2) identify demographic, anatomic, implant/abutment and reconstructive factors associated with implant failure. We hypothesized that there exist discrete, clinician-modifiable factors for implant failure. With regard to our hypothesis, our specific aims were to 1) compare and contrast Kaplan-Meier 1-year survival estimates for delayed versus immediate loaded implants and 2) to identify risk factors associated with implant failures, adjusted for clustered observations (i.e. multiple implants within one patient).^{14–15}

Materials and Methods

Study Design/Sample

This was a retrospective cohort study, consisting of a sample of subjects who had 1 Bicon® dental implant placed at the Dental Implant Centre, a private dental practice located in Boston, MA, during the period of May 1992 – July 2003. The population was subdivided into two groups, based upon the method of loading. Subjects in the delayed loading group had implants placed during the period of May 1992 – July 2000, those in the immediate loading group had implants placed from September 2001 – July 2003. Subjects were excluded from the sample if they had missing charts.

Study Variables – Predictors

The predictor variables (sets of exposures possibly linked to failure) were classified as primary or secondary. The primary predictor variable was the method of loading: delayed or immediate. Immediate-loading was defined as having an implant provisionally restored and stabilized by bonding to adjacent teeth or implants and placed into functional occlusion the same day as insertion. Delayed-loading was defined as having the implant restored at some time interval after implant insertion that was not on the same day as implant insertion.

The secondary predictor variables were broadly categorized as demographic (age at time of first implant, gender, current tobacco use), anatomic (implant location, bone quality (I – IV)), implant/abutment (diameter, length, coating, staging, well size), and reconstructive (sinus lift procedure, barrier membrane, bone graft, ridge split, and graft materials). Bone

quality (Type I–IV) was assessed by the operating surgeon by noting the appearance of bone on the flutes of the reamer on the reaming instrument used to prepare the implant site upon withdrawal from the osteotomy site, as described in the literature.¹⁴ Bone was classified as Type I if the bone was compact and cortical in appearance, Type II when red and filled the flutes of the reamer, and Type IV bone when no bone filled the flutes of the reamer. Bone quality between the appearance of Type II and IV bone was classified as Type III bone. The implant well accommodates the restorative abutment and comes in two sizes, 2 and 3 mm in diameter (see Figure 1).

Study Variables – Outcomes

The outcome variable was implant failure, defined as removal of the implant. The outcome variable was recorded in months as the time to failure or study endpoint, defined as the last visit on record.

Data Analysis

Data were entered into a statistical database (SAS v.8.2, © SAS Institute, Carey, NC, 2001). Descriptive statistics were computed for the sample to provide a general description of the population and to identify differences, if any, between distribution of covariates between the delayed and immediate loading groups. Kaplan-Meier survival analyses were used to compare the 1-year implant survival for the two study groups. Univariate Cox proportional hazards modeling was subsequently used to identify exposures associated with implant failure. Exposures with $p < 0.15$ and biologically relevant measures (age, gender) were included in a marginal Cox regression model, which was used to evaluate the simultaneous effects of multiple covariates and control for correlated, clustered observations (i.e. multiple implants within a single patient).

Results

Descriptive statistics for the study population grouped by loading parameter are summarized in Table 1. The study sample consisted of 855 subjects who had 2826 dental implant placed during the study period. Of these subjects, 677 (79.2%) had delayed loading of 2349 (83.1%) implants, while 178 (20.8%) had 477 (16.9%) immediately loaded dental implants. For the demographic variables, there were no statistically significant differences between the delayed and immediate loading groups ($p = 0.60$). For the anatomic variables, subjects in the immediate loading group were statistically significantly more likely to have implants in the maxilla and placed anteriorly ($p < 0.01$). In addition, the distribution of implant diameters and lengths used was different between the two study groups ($p < 0.01$). Subjects within the immediate loading group were also more likely to have hydroxapatite-coated implants ($p < 0.01$), 3 mm wells ($p < 0.01$), and immediate implants ($p < 0.01$). The immediate loading group was less likely to have an associated dentoalveolar reconstructive procedure ($p < 0.01$).

The Kaplan-Meier estimates of implant survival according to loading group are summarized in Table 2. The one-year survival estimates for the delayed and immediate loading groups

were 95.5% (95% CI: 94.6, 96.4) and 90.3% (95% CI: 87.0, 93.7), respectively. The difference in the one-year survival estimates was statistically significant ($p < 0.01$).

Table 3 provides a summary of the exposures that were statistically or near statistically significantly ($p = 0.15$) associated with implant failure in the univariate Cox proportional hazards model. In the univariate analyses, immediate loading, current tobacco use, maxillary implants, immediate implants, shorter implants, and larger well size were associated with increased risk of failure.

The adjusted marginal multiple Cox regression model is summarized in Table 4. In the multiple model, immediate loaded implants were 2.7 (95% CI: 1.2, 5.9) times more likely to fail at one-year, compared to delayed loaded implants ($p = 0.01$). Implants placed in subjects who reported current tobacco use were 2.6 times more likely to fail at one year, compared to those placed in non-users (95% CI: 1.8, 3.9, $p < 0.01$). Maxillary implants were 90% more likely to fail compared to mandibular implants (HR = 1.9, 95% CI: 1.3, 2.9, $p < 0.01$). For each 1 mm decrease in implant length, there was a corresponding 30% increase in implant failure at one-year (95% CI: 1.2, 1.5, $p < 0.01$). Notably, immediate placement and well size were not statistically significantly associated with time to failure in the multiple model.

Discussion

The purpose of this study was to estimate implant survival in the delayed versus immediate loading group and to identify risk factors associated with implant failure. We hypothesized that there exist discrete factors associated with dental implant failure, and that some, if not all, of these factors could be modified by the clinician to decrease the likelihood of implant failure. To address this hypothesis, we enrolled a retrospective cohort of subjects and evaluated implant survival at one-year, controlling for type of loading and potential confounders/effect modifiers using a modified Cox regression approach for clustered observations.

The overall one-year implant survival for our sample was statistically significantly different between the delayed and immediate loading groups. A higher proportion of the delayed loaded implants survived at one-year, compared to the immediately loaded implants. In a univariate Cox proportional hazards model, we identified numerous potential confounders/effect modifiers of the association between loading and implant failure. After adjusting for the simultaneous effects of these covariates in a marginal multiple Cox regression model, we identified four discrete factors that were associated with implant failure: loading, tobacco use, jaw position, and implant length. We found that, after controlling for potential confounders and effect modifiers, immediately loaded implants were approximately 3 times more likely to fail within one year of placement, compared to delayed loaded implants. In addition, implants placed in tobacco users were more likely to fail than those in non-users, those placed in the maxilla were more likely to fail than those placed in the mandible implants and shorter implants were more likely to fail than longer implants, even after controlling for type of loading.

The results of this study are consistent with those reported in previous studies in that they suggest common, identifiable risk factors for dental implant failure: immediate loading, tobacco use, maxillary implants and short implants.^{8–16} These risk factors have been discretely identified in numerous studies as consistently associated with failure, independent of the type of implant system used. However, we believe this to be the first study evaluating delayed versus immediately loaded implants using a marginal Cox regression controlling for correlated, clustered observations (i.e. controlling for multiple implants within the same patient, which, statistically speaking, cannot be treated in the same manner as multiple implants spread across multiple patients).

There are a number of limitations associated with the design of this study that need to be addressed. Given the retrospective nature of this study, loss to follow-up may be a significant issue, as we only chose to include those subjects who had complete records of their implant surgery and post-operative follow-up. Thus, our study population does not include those patients who may have had implants placed but failed to follow-up. These losses to follow-up could potentially be related to failure – i.e. a subject with an implant that is failing may be reluctant to return to the surgeon who placed the implant and may go elsewhere for re-treatment. We cannot make any generalizations about these patients – the data presented herein apply only to those patients who choose to follow-up. In addition, data in this study were available from only one study center, which, while ensuring a relatively consistent environment for placement and observation, does not account for the variability that is present in other centers with other practitioners. Third, the follow-up time points for the study sample were not uniform – i.e. some patients followed up at 4-week intervals, others at 6-week intervals, and others more or less sporadically. Finally, there is no long-term data available for the immediate loading group, so we cannot quantitatively assess the long-term outcomes for immediately loaded implants.

The results of this study suggest that immediately loaded implants are more likely to fail at one-year when compared to delayed loaded implants, and that current tobacco use, maxillary implants and decreasing implant length are associated with failure. When making a clinical decision regarding immediate loading of dental implants, the practicing surgeon should proceed accordingly to minimize risk for failure whenever possible.

Acknowledgments

Funding Sources/Acknowledgments

This project was supported in part by the Center for Applied Clinical Investigation and the Education and Research Fund, Department of Oral and Maxillofacial Surgery and the Massachusetts General Physicians' Organization, Massachusetts General Hospital, Boston, MA.

The authors would also like to acknowledge the clinicians and staff at the Bicon Dental Implant Centre, Boston, MA for their co-operation and unfettered access to their patient records.

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Figure 1. Image depicting well-size measurement

Well-size was measured as the diameter at the occlusal extent of the implant, to which the diameter of the abutment was adapted. Well-size was not necessarily consistent with implant diameter.

Table 1

Descriptive Statistics for Study Groups

	Delayed (n0 = 677 patients, k0 = 2349 implants)	Immediate (n1 = 178 patients, k1 = 477 implants)	p-value
Demographic Variables			
Age (years) (n0 = 656, n1 = 178)	53.1 ± 13.8 (16.9 – 92.5)	53.0 ± 16.2 (14.9 – 91.4)	0.6
Gender (Male) (n0 = 677, n1 = 178)	336 (49.6)	85 (47.8)	0.75
Current Tobacco Use (Yes)	57 (10.3)	16 (9.0)	0.81
Anatomic Variables			
Jaw (k0 = 2349, k1 = 477)			< 0.01
Maxilla	1415 (60.2)	361 (75.7)	
Mandible	934 (39.8)	116 (24.3)	
Location (k0 = 2349, k1 = 477)			<0.01
Anterior	731 (31.1)	253 (53.0)	
Posterior	1618 (68.9)	224 (47.0)	
Bone Quality (k0 = 1830, k1 = 164)			0.53
Type I	16 (0.9)	7 (4.3)	
Type II	486 (26.6)	16 (9.8)	
Type III	370 (20.2)	58 (35.4)	
Type IV	958 (52.4)	83 (50.6)	
Implant/Abutment Variables			
Implant Diameter (k0 = 2203, k1 = 477)			< 0.01
3 – 3.5 mm	779 (35.4)	55 (11.5)	
4 – 4.5 mm	931 (42.3)	225 (47.2)	
5 mm	436 (19.8)	166 (34.8)	
6 mm	57 (2.6)	89 (6.5)	
Implant Length			< 0.01
6 mm	34 (1.6)	0 (0.0)	
8 mm	449 (20.5)	11 (2.3)	
11 mm	1584 (72.3)	327 (68.6)	
14 mm	125 (5.7)	139 (29.1)	
Coating (k0 = 2074, k1 = 477)			< 0.01
Uncoated	444 (21.4)	7 (1.5)	
TPS	619 (29.9)	28 (5.9)	
HA	1011 (48.8)	441 (92.7)	
Well Size (k0 = 2342, k1 = 477)			< 0.01
2mm	2129 (90.9)	95 (19.9)	
3mm	213 (9.1)	382 (80.1)	
Immediate Implant (Yes) (k0 = 2349, k1 = 477)	243 (10.3)	239 (50.1)	< 0.01
Reconstructive Variables			
Dentoalveolar reconstructive procedure (Yes)	848 (36.1)	43 (9.0)	< 0.01

Table 2

Kaplan-Meier One-Year Survival Estimates

Time (months)	% Survival (95% CI)		p-value
	Delayed	Immediate	
12	95.5 (94.6, 96.4)	90.3 (87.0, 93.7)	< 0.01

Table 3

Univariate Cox Proportional Hazards Models (associations with p < 0.15)

Predictor	Hazard Ratio (95% CI)	P-value
Immediate Loading	1.9 (1.3, 2.8)	< 0.01
Age at Implant Placement	1.0 (1.0, 1.0)	0.26
Gender (Female)	1.1 (0.81, 1.5)	0.51
Current Tobacco Use (Yes)	2.5 (1.7, 3.6)	< 0.01
Jaw Position (Maxilla)	1.7 (1.2, 2.3)	< 0.01
Implant Length (Shorter)	1.2 (1.1, 1.3)	< 0.01
Immediate Implant	1.4 (0.92, 2.0)	0.12
Well Size (3 mm)	1.8 (1.2, 2.6)	< 0.01

* All hazard ratios listed are with respect to the following referent categories: loading (immediate versus delayed (referent)), gender (female versus male (referent)), current tobacco use (yes versus no (referent)), jaw position (mandible versus maxilla (referent)), implant length (shorter versus longer (referent)), placement (immediate versus delayed (referent)), well size (3 mm versus 2 mm (referent)).

** Hazard Ratios > 1 suggest an increased risk for implant failure

Table 4**Marginal Multiple Cox Regression Model**

Predictor		P-value
Immediate Loading	2.7 (1.2, 5.9)	0.01
Age at Implant Placement	1.00 (0.98, 1.0)	0.57
Gender (Female)	1.10 (0.78, 1.5)	0.59
Current Tobacco Use	2.6 (1.8, 3.9)	< 0.01
Jaw Position (Maxilla)	1.9 (1.3, 2.9)	< 0.01
Implant Length (Shorter)	1.3 (1.2, 1.5)	< 0.01
Immediate Implant	1.04 (0.61, 1.8)	0.88
Well Size (3 mm)	0.72 (0.37, 1.4)	0.34

* All hazard ratios listed are with respect to the following referent categories: loading (immediate versus delayed (referent)), gender (female versus male (referent)), current tobacco use (yes versus no (referent)), jaw position (mandible versus maxilla (referent)), implant length (shorter versus longer (referent)), placement (immediate versus delayed (referent)), well size (3 mm versus 2 mm (referent)).

** Hazard Ratios > 1 suggest an increased risk for implant failure