Risk Factors Associated with Implant Failure

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Dedication

I dedicate this thesis to my future husband, Brandon Kelly, for his un-ending love, patience and support, and to my parents, Greg and Paula Schmalz, for all the pep-talks, support, financial and otherwise, and for always telling me to never give up in pursuing my dreams.

Abstract

Objective and Background: Implants have become a predictable treatment for the replacement of missing teeth. However, they are not without problems. It is important to understand the relationship between implant failure and patient- and implant-level factors. Therefore, the purpose of this retrospective chart review was to explore patient- and implant-level factors associated with implant failure, defined here as the loss, removal, or scheduled removal of the implant.

Methods: Data were abstracted from charts of patients at the University of Minnesota School of Dentistry. Patient-level variables included current smoking status, gender, age, self-reported diabetes, and history of bisphosphonate use. Implant-level variables included implant brand, location, whether sinus or bone augmentation was done, immediate or delayed implant placement and restoration type. Data were entered into a custom, web-based data file. Implant failure was defined as the loss or planned removal of the fixture. Descriptive statistics were computed for patient- and implant-level variables. Hazard ratios (HR) and p-values were calculated using Cox proportional hazards regression. The relationship between the variables and implant failures were explored in both univariable and multivariable analyses. We analyzed data for all implants and separately for implants placed in the posterior maxilla.

Results: Smoking was the only patient-level variable associated with implant failure in the univariable analyses (P=0.0109, HR=2.13). Sinus grafting material significantly affected implant failure in both univariable and multivariable analyses (P=<0.0001). Implant-level variables such as length, jaw region, alveolar ridge grafting, and sinus grafting both prior to and at the time of implant placement were not significantly associated with failures (P=>0.05) in the univariable analysis. In the multivariable analysis, overdentures had a failure rate 2.95 times greater than single crowns. In addition, sinus grafting material (P=<0.0001) and bone grafting material (P=0.006) were also significant in the multivariable analysis for all sites. When limiting the multivariable analysis to posterior maxillary sites only bone grafting material was no longer significant, while both restoration type and sinus grafting material remained statistically significant. Interestingly, timing of ridge augmentation, either prior to or at the time of implant placement did not affect implant failure (HR=0.97).

Conclusions: Overall, implants are a predictable treatment option. Smoking negatively affects implant success. Implants supporting overdentures have higher failure rates when compared to those supporting single or multiple fixed restorations and fixed-detachable appliances. Self-reported diabetes, use of bisphosphonates and timing of ridge augmentation were not associated with implant failure.

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Dental implants have become an integral part of contemporary dental therapy. Implants provide an alternative treatment to traditional removable prostheses or tooth supported fixed partial dentures. Overall dental implants have a high survival rate when placed in healthy patients [1]. Dental implants have become a predictable treatment for replacing missing teeth during a patient's dental therapy.

Dental implants, however, are not without complications. Many factors can contribute to implant complications. Cigarette smoking is one factor associated with higher implant failure rates. It is estimated that the risk of implant failure is doubled in smokers compared to non-smokers[2-5]. Failure rates of up to 20% have been reported in smokers [2]. Mundt et al. reported a relationship between implant failure rates and smoking duration [6]. Patients who smoke more than 20 cigarettes per day have a 20% higher relative risk for implant failure when compared to patients who smoke less [7, 8]. Smoking is particularly deleterious in patients with a history of sinus grafting [9] or with poor bone quality [10]. Finally, among smokers, failures seem to occur most frequently within the first two years following placement [11]. Later failures are less common.

Although most systemic conditions have not been shown to affect implant survival, certain conditions and medications like diabetes mellitus and bisphosphonates (BPP) have been shown to adversely affect implant survival and success [12]. Patients with poorly controlled patients with type I diabetes (A1c >7) has been shown to have slower bone turnover, increased the risk for bone fracture, decreased levels of osteointegration and lower bone density surrounding implants [13-15]. It is estimated that patients with diabetes are at 2.5 times greater risk for implant failure when compared to patients without diabetes [16]. Zupnick et al. noted that implant failures occur in patients without diabetes began within a few months after placement and continues over a ten-year period [11]. The effects on implant survival among poorly controlled type II diabetic patient has yet to be fully understood. However, it has been speculated that implants integrate more slowly in patients with poorly-controlled diabetes [13, 17].

Bisphosphonates (BPs) are medications often used in the treatment of osteoporosis and cancers that either affect bone (e.g., multiple myeloma) or that frequently metastasize to the bone (e.g., breast cancer). BPs work by affecting mononuclear cell activity, which in turn disrupts osteoclast bone resorption and increases osteoclast apoptosis. BPs also decreases osteoblast deposition of bone and therefore decrease overall rate of bone turnover [18]. BP-related osteonecrosis of the jaws (BRONJ) was first described by Ruggiero et al., in 2004 [19]. BRONJ is characterized as non-healing painful lesion that usually developed after some sort of trauma to the alveolar bone with a duration of longer than eight weeks. BRONJ occurs more frequently in patients who have been treated with higher intravenous doses of BPs [20]. BRONJ occurs spontaneously in approximately 1 in 10,000 cases of patients previously treated with high intravenous doses of BPs. However, with the addition of trauma to the alveolar bone from either a dental extraction or implant placement the risk of developing BRONJ is estimated to increase to 1 in 1,000 cases [18]. The effect of oral consumption of bisphosphonates is minimal on implant success rates in contrast of that of IV BPs [21, 22].

Some studies have associated increased age (over 60 years) with an increase in implant failure, while other studies failed to show an adverse affect of age on osseointegration of implants [11, 23, 24]. Genetic variability among patients may have a more profound effect on implant success than we are able to understand currently. This may contribute to the clustering of implant failures in a smaller number of patients. Fortunately the majority of implant patients do not have any complications. Yet, a small number of patients have multiple implant failures [25].

Bone quality and density have also been associated with implant success. Bone quality was first described by Lekovic and Zarb in 1985 [26]. They classified bone according to the following types: I, homogenous cortical bone; II, thick cortical bone with minimal medullary bone; III, thin cortical bone with medullary bone of good quality; IV thin cortical bone with medullary bone of poor quality [26]. Studies have shown good success when implants are placed in type I-III bone according to the Lekovic and Zarb classification. This might be related to greater initial implant stability in type one, two or three bone. Lower success rates noted in type four bone might be attributed to an inability to attain primary stability at the time of implant placement [8, 27, 28].

Residual alveolar bone height is another important factor for implant success [23, 29]. Studies have reported higher failure rates for implants less than 10 mm in length [28]. Olate et al. reported failure rates of 9.9% for short (6-9 mm) implants, 3.0% for intermediate-length (10-12 mm) and 3.4% for long (13-18 mm) implants[30]. In general, the literature suggests that implant survival is highest when there is sufficient alveolar bone to accommodate the placement of a longer (≥10 mm) implant. Alsaaadi et al. estimated that implants with less <10 mm in length had a 1.7 times greater odds of failing versus than implants >10 mm in length [8]. However, Misch et al. found that nine-millimeter implants placed in type two and three bone had an overall success rate of 98.9% [31]. In general though, the literature suggests that implant survival is highest when there is sufficient alveolar bone to accommodate the placement of a longer (≥10 mm) implant.

Many studies have shown that implant success rates decrease when implants are placed in severely resorbed areas of the jaw where minimal native bone exists to support an implant length of greater than or equal to10 mm [3, 32, 33]. The majority of these studies were conducted with smooth (machined) surface implants, that are known to have higher failure rates than roughened surface implants [34]. Shorter implants may be necessary for severely resorbed area, but even with roughened surface implants, there is evidence of higher failure rates [30, 35]. This is particularly true in the maxillary arch.

Patients with a history of severe periodontitis or long-standing edentulism often present with severely resorbed jawbones. For these patients, it is often necessary to augment the alveolar ridge or maxillary sinus using autografts, allografts or xenografts. These procedures may be preformed prior to or in conjunction with implant placement. Studies have shown that bone augmentation is predictable and that implants placed into augmented bone have similar survival rates when compared to implants placed in native bone [36-38]. In the edentulous posterior maxilla where the maxillary sinus has pneumatized, sinus augmentation may be indicated. If, less than eight millimeters of bone exist between the alveolar crest and the sinus floor sinus augmentation should be considered in conjunction with implant placement [3].

Sinus augmentation can be a predictable procedure in certain patient populations. Sinus augmentation has been shown to have a 92.2% success rate and has not been shown to contribute to implant failure rates [39]. It has been shown that there is no difference between the different sinus augmentation techniques with respect to implant failure rates

[24]. However, smoking has a negative effect on both implant success and sinus augmentation. Lin et al. reported implant success rate in grafted sinuses was 87% in non-smokers and 79% in smoker one-year after restoration [40]. They also noted that if there was less than four millimeters of native bone at the time of implant placement the success rate was 82% for non-smokers and 60% for smokers.

Another factor that appears to affect implant success is the presence or history of periodontal disease. Studies consistently report increased implant failure rates in patients with a history of periodontal disease [41-43]. However, Karoussis found that implant failure rates after five years were comparable in patients both with or without a history of chronic periodontitis [43]. Patients with implants and a history of periodontitis are at an enhanced risk for developing peri-implantitis. *P. gingivalis, T. denticola*, and *T. forsythia*, are bacteria commonly associated with chronic periodontitis and also found at peri-implantitis sites [44, 45].

Different types of implant characteristics have been related to implant success rates. Implants with roughened surfaces have higher success rates when compared with machined surfaces [3, 46, 47]. Implant length and width can also contribute to implant failures or complications. Implants wider than five millimeters or shorter than ten millimeters have been shown to have higher failure rates [8, 32, 33, 48]. The odds ratio of a five millimeter diameter implant failing when compared to a narrower diameter implant (3.75 or 4 mm implant) is 2.7[8].

The type of prosthesis may also contribute to late implant failures. Late failures are considered to occurs once the prosthesis is placed. Single tooth implant-supported restoration survival rate is estimated at about 97.7% after five years and 94.9% after ten years [1]. Survival rates were slightly lower when a multiple-unit versus a single-unit fixed implant supported restoration was used, (93.6% and 86.7% success rates after five and ten years, respectively) [1]. Earlier studies showed success with fixed restorations in either the maxilla and mandible, while removable implant supported restorations were found to be predictable in the mandible but not the maxilla [32, 33, 49, 50]. Fixed implant- supported prostheses in either the maxilla or mandible had a success rate of 87.7% and 96.7%, respectively, after five years [51]. Removable implant-supported prostheses in the mandible are predictable options for the edentulous patient with a success rate of 95.7% after five years [51]. However, removable implant-supported maxillary prostheses are a less predictable treatment option having a success rate of only 76.6% after five years [51]. Complications and restorative repairs are also higher with implant-supported overdentures when compared to fixed restorations [52, 53].

Implant failures are a multifactorial and complex problem. It is important to understand which patient and implant factors are more likely to adversely affect an implant's success. Several studies have examined the effects of a limited number of patients, or implant characteristics on implant success. However, few studies, however, have included enough patients or implants to simultaneously examine the effects of multiple factors on implant survival. Such an analysis could provide valuable guidance to clinicians providing implant therapies for patients. Therefore, the purpose of this retrospective chart review was to explore patient- and implant-level factors that contribute to implant failure, defined here as the loss or removal or scheduled removal of the implant.

Material and Methods

Protocol

This study was a retrospective chart review of patients who had an implant(s) placed and restored by faculty, residents and students at the University of Minnesota School of Dentistry from 2000 to 2007. The study was approved by the Institutional Review Board at the University of Minnesota. All patients who contributed data had signed the School's Level 1 Consent Form, through which they consented to have their records reviewed for research purposes. No Private Health Information (PHI) was recorded in the data entry file. A link was maintained between the patients' PHI and a four-digit identification number for the duration of the study and then destroyed after data collection was completed. Data abstractions were performed by six individuals who had undergone both IRB and HIPAA training. All individuals were trained and standardized by one researcher (ES). Data was collected from the dental school charts of patients and entered using a web-based application (Research Electronic Data Capture (REDCap) developed by Vanderbilt University). REDCap is a secure online data entry system maintained by the University of Minnesota's Clinical and Translational Science Institute (8UL1TR000114-02 from the National Center for Advancing Translational Sciences). An example of the electronic data entry form is provided in Figure 1.

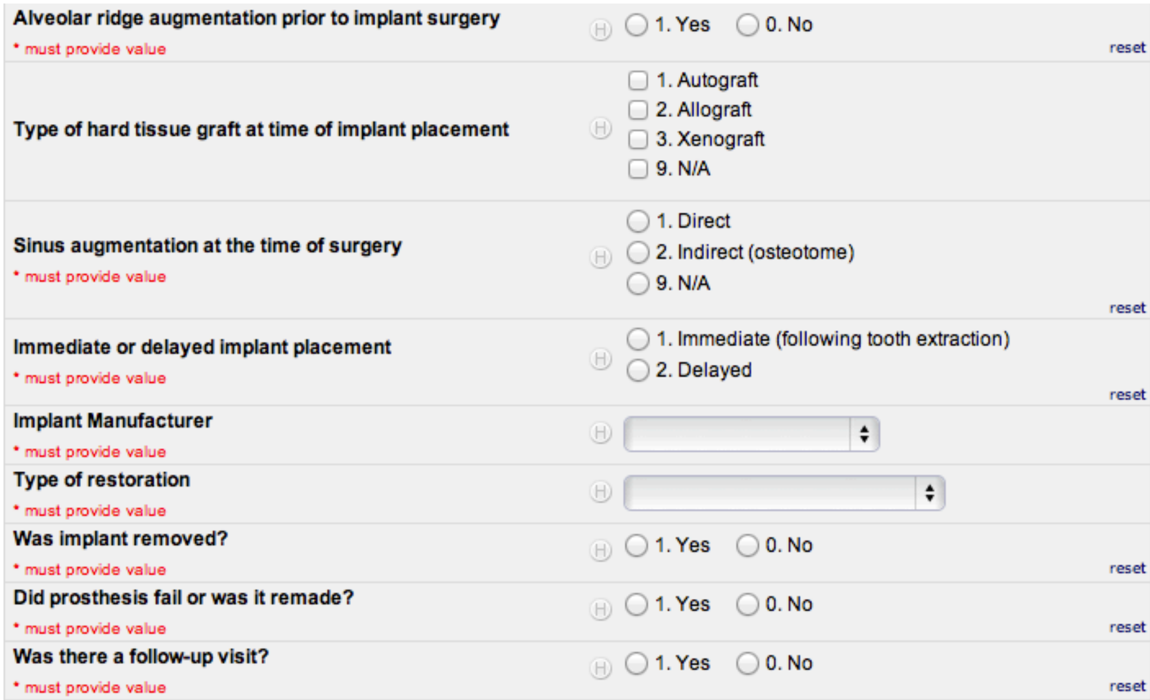
Study Variables

The following patient-level or implant-level information was abstracted from each dental record: age (years), sex (M/F), history of bisphosphonate use (Y/N), current smoking status at the time of implant placement (Y/N), history of diabetes mellitus (Y/N, I or II), surgeon (faculty or resident), restorative dentist (undergraduate dental student, graduate resident or faculty), implant site (tooth number), defining of adjacent site (mesial and distal) to the implant site (natural tooth, implant or edentulous site), implant length and width (mm), whether sinus augmentation was done prior to at the time of implant placement or simultaneously and which osseous augmentation materials were used (autograft, allograft, xenograft, membrane), and amount of remaining native bone (from sinus floor to crest, in mm, when a direct sinus lift was done at the time of implant placement). This latter parameter was evaluated by a single examiner (ES) from pre-operative panoramic radiographs and adjusted for 20% magnification. Additional study variables recorded included whether the implant site(s) was grafted prior to or at the time of implant placement (Y/N) and which materials were used (autograft, allograft, xenograft, membrane), whether it was a delayed or immediate implant placement (Y/N), type of implant (brand), type of restoration (single unit, multiple unit fixed, overdenture, fixed detachable appliance), date of implant failure and prosthesis failure and the date of the last follow-up visit (for non-failed implants). Initially all patient data was included in the study, but after 2005, patients with less than six months follow up from the time of delivery of the permanent restoration were excluded from the study. Patient information was also excluded if the implant was restored outside of the School of Dentistry. Implants were restored either as a single unit, multiple fixed units, fixed detachable prosthesis or an implant-retained overdenture. Implant systems used during this period are listed in Table 1. Implant failure was defined as an implant that was either removed or scheduled for removal, typically because to excessive bone loss or implant mobility.

Data Analysis

Descriptive statistics (means, standard deviations, medians, and quartiles for continuous variables and counts and percentages for categorical variables) were calculated for the study population at both the patient and implant levels. Descriptions of the timing and number of implants placed were also calculated. Univariable and multivariable Cox proportional hazard regressions were computed to assess the association between patient-level and implant-level factors. Due to the potential correlation for multiple implants in one patient, robust variance estimates were computed using General Estimating Equations (GEE). Consequently, hazard ratios are interpreted at the marginal or population level. To address any potential correlation or bias for subsequent implants after the first implant was removed, implants that replaced failed implants were excluded from the analysis. For patients who received implants over multiple visits –occasionally spanning several years - we only considered in the analyses implants placed during the initial surgery or surgeries, which could be separated by as much as three months. Estimated survival plots are presented for each univariable analysis along with the corresponding hazard ratio, confidence interval and p-value. A pre-specified multivariable Cox regression model was used for analyzing the implant survival and its association with age (treated as a linear relationship), smoking status, bone grafting at the time of implant placement, sinus grafting, restoration type, immediate versus delayed placement, as well as jaw region (posterior maxilla, posterior mandible, anterior maxilla, anterior mandible), on the main outcome: implant failure.

Subject's age, in years * must provide value	(H)	[ ]
Bisphosphonate Use * must provide value	(H)	◯ 1. Yes ◯ 0. No reset
Current smoking status * must provide value	(H)	◯ 1. Smoker ◯ 0. Non-smoker reset
History of diabetes * must provide value	(H)	◯ 1. Yes ◯ 0. No reset
Surgeon placing implant * must provide value	(H)	◯ 1. Resident ◯ 2. Faculty reset
Restorative dentist * must provide value	(H)	◯ 1. Faculty ◯ 2. Resident ◯ 3. Pre-doctoral student ◯ 4. Outside dentist reset
Date of implant placement * must provide value	(H)	[ ] Today M-D-Y
Tooth site * must provide value	(H)	[ ] 1-32
Mesial adjacent finding * must provide value	(H)	◯ 1. Natural tooth ◯ 2. Implant ◯ 3. Edentulous space reset
Distal adjacent finding * must provide value	(H)	◯ 1. Natural tooth ◯ 2. Implant ◯ 3. Edentulous space reset
Length of implant, in mm * must provide value	(H)	[ ] 8.0 - 18.0 mm
Width of implant, in mm * must provide value	(H)	[ ] 3.0 - 6.5 mm
Sinus augmentation prior to implant surgery * must provide value	(H)	◯ Yes ◯ No reset


Alveolar ridge augmentation prior to implant surgery
* must provide value
1. Yes 0. No
reset

Type of hard tissue graft at time of implant placement
1. Autograft
2. Allograft
3. Xenograft
9. N/A

Sinus augmentation at the time of surgery
* must provide value
1. Direct
2. Indirect (osteotome)
9. N/A
reset

Immediate or delayed implant placement
* must provide value
1. Immediate (following tooth extraction)
2. Delayed
reset

Implant Manufacturer
* must provide value

Type of restoration
* must provide value

Was implant removed?
* must provide value
1. Yes 0. No
reset

Did prosthesis fail or was it remade?
* must provide value
1. Yes 0. No
reset

Was there a follow-up visit?
* must provide value
1. Yes 0. No
reset

Figure 1. REDCap data entry form

Table 1: Implant Brands	
3i Certain	Lifecore Sustain
3i Certain Prevail	Micro-vent
3i External Hex	Nobel Replace
Astra	Screw-vent/ Zimmer
Branemark Machined surface	Steri-Oss
Imtec	Other
Lifecore Restore	

Table 1. Implant systems placed at the Minnesota School of Dentistry and included within this chart review

Results

Data on a total of 3318 implants was collected from this study population. Only 3020 implants placed in 1259 patients with 115 implant failures were included in the analysis of this study. Two-hundred and ninety-eight implants were excluded from the analysis because of incomplete data collection, because they were placed more than 3 months after the patient's initial implant surgery or because they replaced a failed implant. A description of patient-specific characteristics can be seen in Table 2. The average age (+/- standard deviation) of the population was 52.3 +/-16.2 years, and ranged from 16 to 91 years of age.

A description of implant site-specific characteristics are summarized in Table 3. The average follow-up time after implant placement was 3.56 years (16-89 years of age).

A univariable Kaplan-Meier Analysis is shown in Figure 2. To illustrate the number of all failures over time. The majority (108) of the implant failures occurred within the first 3.4 years of follow-up. One hundred fifteen failures occurred in 87 patients, with 70 patients having only one failure and 17 patients having multiple failures.

Estimated survival plots for the different variables can be seen in Figures 3-15. The survival rates, *hazard ratios* and *p-values* for the different variables are given in Tables 4-16. Among all the patient-level variables, only smoking was significantly associated with implant failure. Current smokers were at significantly higher risk of implant failure at one, three and five years when compared to non-smokers (P=0.0109, HR=2.13) (Table 5, Figure 4).

Sinus grafting material was the only implant-level variable significantly associated with implant failure (P<0.0001, Table 12). Sinus grafting hazard ratios showed that allograft when used alone or in combination with autograft resulted in higher failure rates than when no grafting material was used. Xenograft when used alone also had a higher failure rate when compared to when no sinus grafting was performed. The hazard ratios for the variable, restoration type, approached statistical significance (P=0.0513). Fixed detachable appliances and fixed implant-supported bridges performed better than single unit crowns, while all three restorations performed better than implants supporting overdentures.

Results of the multivariable modeling (including all implants) are summarized in Table 17. The corresponding *hazard ratios* are listed in Table 18. Restoration type, bone grafting and sinus grafting were all significantly associated with failures ($P \leq 0.05$). Jaw region, age, smoking and immediate versus delayed placement did not contribute to an increase in implant failure.

An additional multivariable analysis limited to maxillary posterior teeth estimated the effects of sinus grafting and the different types of materials used (Table 19). This model included the variables age, smoking, restoration type, bone graft at the time of implant placement and sinus grafting at the time of implant placement. Restoration type and sinus grafting at the time of implant placement significantly affected implant failure ($P \leq 0.05$). Age, smoking and bone grafting at the time of implant placement did not have a significant affect on implant failure. The hazard ratios for this model are given in Table 20.

Discussion

This study evaluated both patient- and implant-level factors to determine how they contribute to implant failure. This retrospective chart review revealed that smoking significantly increases the risk of implant failure both initially and over a period of five years. Smoking's adverse affect on implant survival has been documented in many other studies [2-7, 9-11, 54]. This chart review found implant loss in smokers occurred at a steady rate that was significantly greater than non-smokers. This is in contradiction to the result of Moy 2005, who found that the majority of failures in smokers occurred within the first two years and then tapered off with fewer failures after two years. Moy's study was of similar design and sample size as the current study, but had a longer follow-up (up to 20 years) and larger number of failures (309). All implants were placed by a single surgeon in that study whereas in this study implants were placed by many graduate resident and faculty surgeons. Both Moy's et al. study and the current study concluded that smokers have higher failure rates than non-smokers. The larger number of failures and longer follow-up periods in Moy's et al. study provides stronger evidence on a possible pattern of implant failure in smokers than the current study [11].

Patient factors such as diabetes and bisphosphonate use did not contribute significantly to implant failure in this study. Although we did not assess glycemic control, it is possible that diabetes was not associated with failures because implants may have been placed only in patients whose diabetes was well controlled. It is estimated that patients who were well controlled (i.e, have an hemoglobin A1c <5.7) have an implant failure rate of 2.9%, which is similar to that of implants placed in healthy patients [13, 17]. Patients with type I diabetes have been shown to have decreased bone turnover rates, osseointegration and bone density surrounding implants, while this has not been shown in patients with type II diabetes [13]. The majority of the diabetic patients in this were diagnosed with type II diabetes.

Implant failure was not associated with bisphosphonates use. The majority of patients taking bisphosphonates included in this study were taking oral bisphosphonates, which have been shown not to significantly effect implant failure rates [21, 22, 55].

Patient age did not have a significant effect on implant failure rate. These models suggested that increasing age does not affect implant failure rates. This is inconsistent with the findings of Conrad et al., who concluded that increased age and poor systemic health (ASA III or greater) were both associated with significantly higher implant failure rates [24]. However, their study included only maxillary posterior implants and evaluated a smaller number of implants (504 implants) with less follow-up time when compared to the current study. Another consideration was that biological age may have been a more relevant variable than chronological age. In other words, a patient's overall systemic health and not chronological age most likely has a greater affect on implant success [24].

Regarding implant-level factors, implant length was not associated with implant failure. This finding should be viewed with caution, however, since only four implants were less than 10 mm in length. Too address the skewed distribution of implant lengths, we generated four categories (8-11.5 mm, 12-13 mm and 14-18 mm) that are not typical for such studies. Our finding might have differed had we been able to treat implant length as a ordinal variable. The majority of implants included in this study were at least 10 mm in length, which has been shown to have lower failure rates [8, 30]. Therefore, the comparison of short implants (<10 mm) versus longer implants (≥10 mm) cannot be determined from this study.

Implant failures were not significantly associated with jaw region in the univariable or multivariable analyses. Jang et al. recently reported similar findings in a large retrospective study [56]. However, in this study when determining the survival analysis there is a trend for implants placed in the mandibular anterior to have the highest survival rate over five years, followed by mandibular posterior, maxillary anterior.

Finally the maxillary posterior, with the lowest five-year survival rate. The use of hazard ratios with the multivariable model reveals that implants placed in the mandibular posterior faired slightly better, although this finding was not significant (HR=1.49, P=0.1179) when compared to implants placed in the maxillary posterior. This is consistent with publications, where by implants have a higher failure rate when placed in the posterior maxilla due to the decrease in bone density and quality [27, 28, 54, 57].

We evaluated the effects of sinus and alveolar ridge bone grafting both prior to in conjunction with implant placement. Grafting of the alveolar ridge either prior to or at the time of implant placement was not associated with implant failures. This finding is in agreement with a review by Clementini et al. in which the approximate success rates for implants placed in grafted sites, 90-100%, was comparable to rates observed in non-grafted sites [58]. Interestingly, this study found that whether the site was grafted prior to implant placement or during implant placement did not have an affect on implant failure (HR=0.97). This might imply that treatment times could be shortened by grafting at the same time as implant placement in native bone rather than grafting prior to and then waiting for the grafted site to mature, assuming primary stability can be achieved at the time of placement.

The multivariable model (including all implants) also revealed that bone grafting at the time of implant placement did significantly affect implant failure. However, use of certain grafting combinations, such as allograft plus xenograft, or xenograft alone, had higher hazard ratios when compared to no grafting at the time of implant placement (HR=4.67, 2.05, respectively). However, these findings must be interpreted with caution since both of these groups had a very limited number of patients, with 6 and 22 patients respectively. Consequently, even having one failure in either of these small groups would dramatically increase its statistical affect resulting in a significant higher implant failure rate and a larger hazard ratio.

A multivariable analysis was employed to evaluate the affect of graft material on maxillary sinus elevation and implant failure in maxillary posterior sites (Table 19 and 20). Xenograft when used alone or combined with either autograft or allograft had a significantly lower survival rate over time. This contradicts several other studies that report autogenous bone is the gold standard for sinus augmentation [59-61] Raghoebar et al. reported on twenty-two patients where 47 implants were placed into grafted maxillary sinuses [59]. Kolerman et al, utilized freeze-dried bone allograft to graft the maxillary sinus for implant placement and demonstrated the presence of new vital bone within the sinus [62]. Since the sample sizes of the various grafting material combinations tended to be rather small in this study so patient factors, such as smoking, may have a greater statistical effect than if the information was taken from a larger patient population.

We found no significant difference in implant success rates between implants placed with a direct or indirect sinus lift approach (5-year success rate of 92.7% and 96.1%, respectively). Nor was an association found between residual ridge height at the time of sinus augmentation and implant survival. Findings from both Conrad et al and Testori et al, reported that a residual bone height of less than 4 mm at the time of implant placement resulted in a significantly higher implant failure rate [24, 63] Both of these studies were retrospective chart reviews. Conrad's et al followed 210 implants placed with a direct sinus lift while Testori et al. followed 328 implants. Both studies categorized the amount of residual native bone height at the time of a direct sinus lift and implant placement. They both reported that having less than four millimeters of residual ridge height at the time of implant placement led to significantly higher implant failure rates. Conrad et al. also found the correlation with residual ridge heights ranged from 4-8 mm as well. The reason this study did not find a significant association between implant failure and residual ridge height was because the average residual bone height at the time of implant placement was 6.7 mm. Consequently, well above the 4 mm cut off reported in the other two proceeding studies.

Multivariable analysis did not show any significant difference between immediate versus delayed implant placement. This finding supports that of several other studies [64, 65].

Analysis of the type of implant supported restoration placed revealed fixed-detachable appliance had the highest survival rate, followed by fixed implant-supported partial dentures, single crown and lastly implant-supported overdenture restorations (P=0.0513). These findings are supported by a long-term study, Ueda et al., that have found the overall success and survival of implant-supported overdentures being around 85% after 10-24 years, which is lower than fixed implant-supported restorations [66]. However, in this study restoration type was significant according to multivariable analyses for all implant sites compared to maxillary posteriors. Overdentures did significantly worse when compared to single tooth implant restorations (HR=2.95), fixed-detachable appliances and fixed implant-supported partial dentures.

Limitations of any retrospective study include only being able to access the information that is supplied by the patient's record, errors or information missing from the patient record that was then transferred to the study data, bias that occurs from surgeon preference in technique or clinical judgment and problems associated with limited sample size, as noted for the sinus material grafting groups.

Data from only 115 failures among 3020 implants placed in 1259 patients was used for statistical purposes. This makes it difficult to establish robust conclusions regarding which variables contribute most or cause implant failure because there were so few failures. A follow-up evaluation might expand our data pool beyond 2007 thereby increasing the patient samples size and potential failures for further analysis.

Conclusions

1) Bone grafting for ridge augmentation at the time of implant placement and sinus grafting at the time of implant placement did not adversely affect implant survival rates.
2) Timing of ridge augmentation (either prior to or at the time of implant placement) did not adversely affect implant failure.
3) Overdentures perform significantly worse than implant supported single crowns, fixed-detachable appliances and fixed partial dentures.
4) When included in multivariable regression analysis of all implant sites age, implant location, smoking and immediate versus delayed implant placement did not contribute to implant failure.
5) Patients with diabetes or patients who had taken bisphosphonates do not experience higher implant failure rates when compared to patients without diabetes and patients not taking bisphosphonates in the general patient population.

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Appendix

Table 2: Descriptive Statistics for Study Population (N=1259)		
	Category	% (N)
Subjects gender		
	Male	44.7% (564)
	Female	55.3% (695)
Subjects age, in years	Q1, Median, Q3	43, 55, 64
	Mean (+/- SD)	52.3 +/- 16.2
Bisphosphonate Use		
	Yes	3.2% (40)
	No	96.8% (1219)
Current smoking status		
	Smoker	11.4% (144)
	Non-Smoker	88.6% (1115)
History of diabetes		
	Yes	4.6% (58)
	Type I	0.2% (2)
	Type II	4.4% (56)
	No	95.4% (1201)
Surgeon placing implant		
	Resident	64.3% (810)
	Faculty	35.7% (449)
Restorative dentist		
	Faculty	37.4% (471)
	Resident	46.2% (582)
	Pre-Doctoral Student	14.0% (176)
	Outside Dentist	2.4% (30)

Table 3: Implant-Level Characteristics		
	N	
Follow-up Time, years	3020	1.33a, 3.11b, 5.15c, (3.56+/-2.62)
Failure Time, years	115	0.42a, 0.73b, 3.41c, (2.06+/-2.31)
Jaw Region	3020	
Mandibular Anterior		15.3% (461)
Mandibular Posterior		32.1% (969)
Maxillary Anterior		21.1% (638)
Maxillary Posterior		31.5% (952)
Implant Manufacturer	3020	
3i Certain		8.2% (249)
3i Certain Prevail		0.3% (9)
3i EX HEX		0.5% (16)
Astra		0.5% (14)
Branemark Machined		1.0% (29)
Imtec		0.1% (2)
Lifecore Restore		17.8% (538)
Lifecore Sustain		18.0% (544)
Micro-Vent		9.7% (292)
Nobel Replace		0.2% (5)
Screw-Vent		41.6% (1255)
Steri-Oss		0.3% (10)
Other		1.9% (57)
Ridge Augmentation	3020	
Ridge Augmentation Prior to Implant Placement		11.4% (345)
Ridge Augmentation During Implant Placement		22.2% (670)
Alveolar Ridge Augmentation Prior to and During Implant Placement		3.0% (92)
No Grafting		63.3% (1913)
Grafting Material Used at time of Implant Placement	3020	
Autograft		4.3% (131)
Allograft		18.5% (558)
Xenograft		0.7% (22)
Autograft and Allograft		1.5% (44)
Autograft and Xenograft		0.0% (1)
Allograft and Xenograft		0.2% (6)
No grafting		74.8% (2258)
Sinus augmentation prior to implant placement	3020	
Grafting		7.7% (232)

No grafting		92.3% (2788)
Sinus graft material prior to implant placement	3020	
Autograft		0.5% (14)
Allograft		3.8% (116)
Xenograft		0.5% (15)
Autograft and Allograft		0.9% (27)
Allograft and Xenograft		0.1% (3)
Membrane		0.2% (6)
Autograft, Xenograft and Membrane		0.2% (5)
Autograft, Allograft and Membrane		0.4% (12)
Allograft and Membrane		0.9% (27)
Xenograft and Membrane		0.0% (1)
No Grafting		92.5% (2794)
Sinus augmentation at the time of implant placement	3020	
Direct		4.1% (124)
Indirect (osteotome)		5.2% (158)
No sinus grafting		90.7% (2738)
Residual Native bone height at time of implant placement, in mm	107	5.0a, 6.0b, 8.0a, (6.7+/-2.9)
Implant Length	3020	
8-11.5		13.3% (403)
12-13.		55.8% (1686)
14-18		30.8% (931)
Implant Width	3020	3.7a, 4.0b, 4.7c, (4.037+/-0.564)
Immediate or Delayed implant placement	3020	
Immediate		8.7% (264)
Delayed		91.3% (2756)
Type of Restoration	3020	
Single Crown		50.2% (1515)
Fixed Implant Bridge		23.4% (707)
Fixed-Detachable Appliance		15.6% (472)
Overdenture		7.8% (237)
Never Restored		2.9% (89)

Lowercase letters represent the 25th percentile (a), the median (b) and the 75th percentile (c) of the distribution for continuous variables.
Numbers in parentheses are
N is the number of observations.
Numbers after percents are frequencies

Table 4. Estimated Survival Rate by Gender				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Male	0.983	0.976	0.990
	Female	0.975	0.967	0.982
Year 3	Male	0.976	0.967	0.985
	Female	0.965	0.955	0.974
Year 5	Male	0.962	0.948	0.976
	Female	0.945	0.930	0.960
			Lower 0.95	Upper 0.95
Hazard Ratio Gender	Gender	0.68	0.42	1.09
p-Value	0.1066			

Table 5. Estimated Survival Rate by Smoking				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Smoker	0.960	0.941	0.980
	Non-Smoker	0.981	0.976	0.987
Year 3	Smoker	0.919	0.919	0.971
	Non-Smoker	0.974	0.967	0.981
Year 5	Smoker	0.913	0.874	0.955
	Non-Smoker	0.958	0.948	0.969
			Lower 0.95	Upper 0.95
Hazard Ratio	Smoker:Non-Smoker	2.13	1.19	3.80
p-Value	0.0109			

Table 6. Estimated Survival Rate by Implants in Patients with and without Diabetes				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Diabetes	0.989	0.974	1.000
	No Diabetes	0.977	0.972	0.983
Year 3	Diabetes	0.985	0.964	1.000
	No Diabetes	0.969	0.962	0.976
Year 5	Diabetes	0.976	0.945	1.000
	No Diabetes	0.951	0.941	0.962
			Lower 0.95	Upper 0.95
Hazard Ratio	Diabetes: No Diabetes	0.48	0.12	1.95
p-Value	0.3028			

Table 7. Estimated Survival Rate by Implants in Patients taking Bisphosphonates				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Bisphosphonates	0.995	0.986	1.000
	No Bisphosphonates	0.977	0.972	0.983
Year 3	Bisphosphonates	0.993	0.981	1.000
	No Bisphosphonates	0.960	0.962	0.975
Year 5	Bisphosphonates	0.990	0.970	1.000
	No Bisphosphonates	0.951	0.941	0.961
			Lower 0.95	Upper 0.95
Hazard Ratio	Bisphosphonates: No Bisphosphonates	0.21	0.03	1.39
p-Value	0.1046			

Table 8. Estimated Survival by Jaw Region				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Mandibular Anterior	0.987	0.977	0.996
	Mandibular Posterior	0.984	0.977	0.991
	Maxillary Anterior	0.975	0.964	0.986
	Maxillary Posterior	0.970	0.959	0.980
Year 3	Mandibular Anterior	0.982	0.969	0.995
	Mandibular Posterior	0.977	0.968	0.987
	Maxillary Anterior	0.966	0.951	0.981
	Maxillary Posterior	0.958	0.945	0.972
Year 5	Mandibular Anterior	0.971	0.951	0.992
	Mandibular Posterior	0.965	0.951	0.979
	Maxillary Anterior	0.947	0.924	0.970
	Maxillary Posterior	0.935	0.915	0.955
			Lower 0.95	Upper 0.95
Hazard Ratio	Mn Anterior: Mn Posterior	0.81	0.37	1.77
Hazard Ratio	Mx Anterior: Mn Posterior	1.52	0.85	2.73
Hazard Ratio	Mx Posterior: Mn Posterior	1.87	1.11	3.16
p-Value	0.0644			

Table 9. Estimated Survival By Grafting				
Year	Category	Survival	Lower 95	Upper 95
Year 1	Grafting During	0.980	0.971	0.989
	Grafting Prior	0.967	0.947	0.986
	Grafting Prior and During	0.975	0.938	1.000
	No Grafting	0.979	0.973	0.986
Year 3	Grafting During	0.972	0.960	0.985
	Grafting Prior	0.954	0.928	0.980
	Grafting Prior and During	0.965	0.914	1.000
	No Grafting	0.971	0.963	0.979
Year 5	Grafting During	0.957	0.938	0.969
	Grafting Prior	0.928	0.889	0.969
	Grafting Prior and During	0.945	0.868	1.000
	No Grafting	0.955	0.943	0.968
			Lower 0.95	Upper 0.95
Hazard Ratio	Grafting During:Grafting Prior	0.97	0.58	1.61
	Grafting Prior:No Grafting	1.63	0.84	3.14
	Grafting Prior and During:No Grafting	1.23	0.26	5.88
p-Value	0.1364			

Table 10. Estimated Survival Rate by Prior Sinus Grafting				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Sinus Grafting	0.967	0.949	0.986
	No Grafting	0.979	0.973	0.984
Year 3	Sinus Grafting	0.955	0.930	0.980
	No Grafting	0.971	0.964	0.977
Year 5	Sinus Grafting	0.930	0.893	0.969
	No Grafting	0.954	0.944	0.965
			Lower 0.95	Upper 0.95
Hazard Ratio Sinus	Graft: No Sinus Graft	1.56	0.87	2.81
p-Value	0.137			

Table 11. Estimated Survival Rate by Grafting at Time of Implant Placement				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Allograft	0.980	0.969	0.990
	Allograft and Xenograft	0.909	0.735	1.000
	Autograft	0.986	0.971	1.000
	Autograft and Allograft	0.978	0.950	1.000
	Autograft and Xenograft	0.998	0.995	1.000
	Xenograft	0.957	0.899	1.000
	None	0.977	0.971	0.984
Year 3	Allograft	0.972	0.957	0.986
	Allograft and Xenograft	0.876	0.652	1.000
	Autograft	0.981	0.960	1.000
	Autograft and Allograft	0.970	0.310	1.000
	Autograft and Xenograft	0.997	0.992	1.000
	Xenograft	0.941	0.863	1.000
	None	0.969	0.961	0.977
Year 5	Allograft	0.956	0.340	0.979
	Allograft and Xenograft	0.813	0.512	1.000
	Autograft	0.971	0.937	1.000
	Autograft and Allograft	0.953	0.895	1.000
	Autograft and Xenograft	0.996	0.988	1.000
	Xenograft	0.910	0.795	1.000
	None	0.952	0.940	0.963
			Lower 0.95	Upper 0.95
Hazard Ratio	Allograft:None	0.91	0.51	1.62
Hazard Ratio	Allograft and Xenograft:None	4.18	0.45	39.19
Hazard Ratio	Autograft:None	0.60	0.18	1.97
Hazard Ratio	Autograft and Allograft:None	0.96	0.25	3.69
Hazard Ratio	Autograft and Xenograft:None	0.08	0.01	0.60
Hazard Ratio	Xenograft:None	1.91	0.45	8.08
p-Value	0.1543			

Table 12. Estimated Survival by Sinus Grafting Materials				
Year	Category	Survival	Lower 95	Upper 95
Year 1	Allograft	0.973	0.949	0.998
	Allograft and Membrane	0.980	0.941	1.000
	Allograft and Xenograft	1.000	1.000	1.000
	Allograft, Xenograft and Membrane	1.000	1.000	1.000
	Autograft	1.000	1.000	1.000
	Autograft and Allograft	0.933	0.874	0.995
	Autograft, Allograft and Membrane	1.000	1.000	1.000
	Membrane	1.000	1.000	1.000
	Xenograft	0.958	0.897	1.000
	Xenograft and Membrane	1.000	1.000	1.000
	None	0.974	0.963	0.985
Year 3	Allograft	0.957	0.921	0.995
	Allograft and Membrane	0.968	0.908	1.000
	Allograft and Xenograft	1.000	0.999	1.000
	Allograft, Xenograft and Membrane	1.000	0.999	1.000
	Autograft	1.000	0.999	1.000
	Autograft and Allograft	0.894	0.809	0.989
	Autograft, Allograft and Membrane	1.000	0.999	1.000
	Membrane	1.000	0.999	1.000
	Xenograft	0.340	0.841	1.000
	Xenograft and Membrane	1.000	0.999	1.000
	None	0.958	0.943	0.974
Year 5	Allograft	0.935	0.882	0.992
	Allograft and Membrane	0.952	0.863	1.000
	Allograft and Xenograft	1.000	0.999	1.000
	Allograft, Xenograft and Membrane	1.000	0.999	1.000
	Autograft	1.000	0.999	1.000
	Autograft and Allograft	0.844	0.725	0.982
	Autograft, Allograft and Membrane	1.000	0.999	1.000
	Membrane	1.000	0.999	1.000
	Xenograft	0.902	0.769	1.000
	Xenograft and Membrane	1.000	0.999	1.000
	None	0.937	0.916	0.959
			Lower 0.95	Upper 0.95

Hazard Ratio	Allograft:None	1.03	0.40	2.64
	Allograft and Membrane: None	0.76	0.10	5.64
	Allograft and Xenograf: None	0.01	0.00	0.03
	Allograft, Xenograft and Membrane:None	0.01	0.00	0.02
	Autograft:None	0.01	0.00	0.03
	Autograft and Allograft	2.62	1.04	6.62
	Autograft, Allograft and Membrane:None	0.01	0.00	0.02
	Membrane:None	0.01	0.00	0.05
	Xenograft:None	1.59	0.33	7.62
	Xenograft and Membrane:None	0.01	0.00	0.05
p-Value	<0.0001			

Table 13. Estimated Survival Rate by Sinus Augmentation at Time of Implant Placement

Year	Category	Survival	Lower 95	Upper 95
Year 1	Direct	0.982	0.961	1.000
	Indirect	0.966	0.943	0.989
	No grafting	0.979	0.973	0.984
Year 3	Direct	0.975	0.946	1.000
	Indirect	0.953	0.923	0.984
	No grafting	0.970	0.963	0.977
Year 5	Direct	0.961	0.917	1.000
	Indirect	0.927	0.882	0.975
	No grafting	0.954	0.943	0.964
			Lower 0.95	Upper 0.95
Hazard Ratio	Direct: No grafting	0.84	0.25	2.78
Hazard Ratio	Indirect: No grafting	1.59	0.8	3.18
p-Value	0.4087			

Table 14. Estimated Survival Rate by Immediate Implant Placement				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Immediate	0.981	0.967	0.996
	Delayed	0.978	0.972	0.983
Year 3	Immediate	0.974	0.954	0.995
	Delayed	0.969	0.962	0.976
Year 5	Immediate	0.960	0.929	0.992
	Delayed	0.952	0.941	0.962
			Lower 0.95	Upper 0.95
Hazard Ratio	Immediate: Delayed	0.83	0.36	1.9
p-Value	0.6581			

Table 15. Estimated Survival Rate by Implant Length				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	8-11.5	0.979	0.968	0.991
	12-13.	0.976	0.969	0.983
	14-18	0.981	0.972	0.990
Year 3	8-11.5	0.972	0.956	0.987
	12-13.	0.967	0.958	0.976
	14-18	0.973	0.961	0.985
Year 5	8-11.5	0.956	0.932	0.979
	12-13.	0.949	0.935	0.963
	14-18	0.958	0.940	0.976
			Lower 0.95	Upper 0.95
Hazard Ratio	8.5-11.5:12-13	0.86	0.48	1.55
Hazard Ratio	14-18:12-13	0.82	0.47	1.42
p-Value	0.7313			

Table 16. Estimated Survival Rate by Restoration Type				
Year	**Category**	**Survival**	**Lower 95**	**Upper 95**
Year 1	Single Crown	0.985	0.979	0.991
	Fixed Bridge	0.989	0.982	0.996
	Fixed- Detachable Appliance	0.995	0.989	1.000
	Overdenture	0.967	0.943	0.992
Year 3	Single Crown	0.978	0.971	0.986
	Fixed Bridge	0.984	0.975	0.993
	Fixed- Detachable Appliance	0.992	0.984	1
	Overdenture	0.954	0.921	0.988
Year 5	Single Crown	0.960	0.946	0.974
	Fixed Bridge	0.971	0.955	0.987
	Fixed- Detachable Appliance	0.986	0.970	1.000
	Overdenture	0.914	0.855	0.978
			Lower 0.95	Upper 0.95
Hazard Ratio	Fixed Bridge: Single Crown	0.72	0.38	1.36
Hazard Ratio	Fixed-Detachable Appliance: Single Crown	0.35	0.1	1.14
Hazard Ratio	Overdenture: Single Crown	2.18	0.93	5.14
p-Value	0.0513			

Table 17. Multivariable Model for all sites	**P**
Region	0.1179
Restoration	<0.0001
Age	0.8833
Smoking	0.1361
Bone Grafting at Time of Implant Placement	0.0006
Sinus Grafting at Time Implant Placement	<0.0001
Immediate vs Delayed	0.6934

Table 18. Hazard Ratio's for Multivariable Analysis for all sites				
Hazard Ratio	Category		Lower 0.95	Upper 0.95
	Age	0.97	0.65	1.45
	Mn Anterior:Mn Posterior	0.53	0.24	1.15
	Mx Anterior: Mn Posterior	1.19	0.66	2.15
	Mx Posterior: Mn Posterior	1.49	0.84	2.65
	Fixed bridge: Single crown	0.74	0.39	1.41
	Fixed-detachable appliance: Single crown	0.48	0.15	1.54
	Overdenture: Single crown	2.95	1.19	7.36
	Never restored:Single crown	25.62	10.92	60.13
	Smoker:Non-smoker	1.74	0.84	3.63
Bone grafting at time of implant placement	Allograft:No grafting	0.75	0.42	1.32
	Allograft and Xenograft: No grafting	4.67	0.47	46.74
	Autograft: No grafting	0.63	0.18	2.22
	Autograft and Allograft: No grafting	0.96	0.29	3.22
	Autograft and Xenograft:No grafting	0.01	0.00	0.07
	Xenograft: No grafting	2.05	0.50	8.43
Sinus grafting at time of implant placement	Allograft:No sinus grafting	0.89	0.38	2.07
	Allograft and membrane: No sinus grafting	1.08	0.15	7.77
	Allograft and Xenograft: No sinus grafting	0.00	0.00	0.01
	Allograft, Xenograft and membrane: No sinus grafting	0.00	0.00	0.02
	Autograft: No sinus grafting	0.01	0.00	0.03
	Autograft and Allograft: No sinus grafting	1.81	0.56	5.79
	Autograph, Allograft and membrane: No sinus grafting	0.00	0.00	0.01
	Membrane: No sinus grafting	0.00	0.00	0.02
	Membrane and Xenograft: No sinus grafting	0.00	0.00	0.02
	Xenograft: No sinus grafting	0.99	0.17	5.84
	Immediate: Delayed	1.19	0.49	2.88

Table 19. Multivariable Model for Maxillary Posteriors only	**P**
Restoration	<0.0001
Age	0.3552
Smoking	0.1048
Bone Grafting at Time of Implant Placement	0.0597
Sinus Grafting at Time Implant Placement	<0.0001

Table 20. Hazard Ratios for Multivariable Analysis for Maxillary Posteriors only				
	Category		Lower 0.95	Upper 0.95
Hazard Ratio	Fixed bridge:Single crown	1.18	0.47	1.08
	Fixed—detachable appliance: Single crown	0.01	0.00	0.01
	Overdenture: Single crown	4.58	1.24	16.93
	Never restored:Single crown	27.47	8.39	89.94
	Smoker:Non—smoker	2.32	0.84	6.42
	Allograft:None	1.05	0.52	2.10
	Allograft and Xenograft:None	6.34	0.56	72.02
	Autograft:None	0.65	0.07	6.02
	Autograft and Allograft:None	0.59	0.10	3.36
	Xenograft:None	8.81	1.93	40.3
	Allograft :None	0.73	0.27	1.91
	Allograft and Membrane:None	1.21	0.16	8.93
	Allograft and Xenograft:None	0.00	0.00	0.01
	Allograft, Xenograft and Membrane:None	0.00	0.00	0.02
	Autograft:None	0.06	0.01	0.33
	Autograft and Allograft:None	1.99	0.71	5.60
	Autograft, Allograft and Membrane:None	0.01	0.00	0.04
	Membrane:None	0.00	0.00	0.03
	Xenograft:None	1.15	0.27	4.91
	Xenograft and Membrane:None	0.00	0.00	0.04

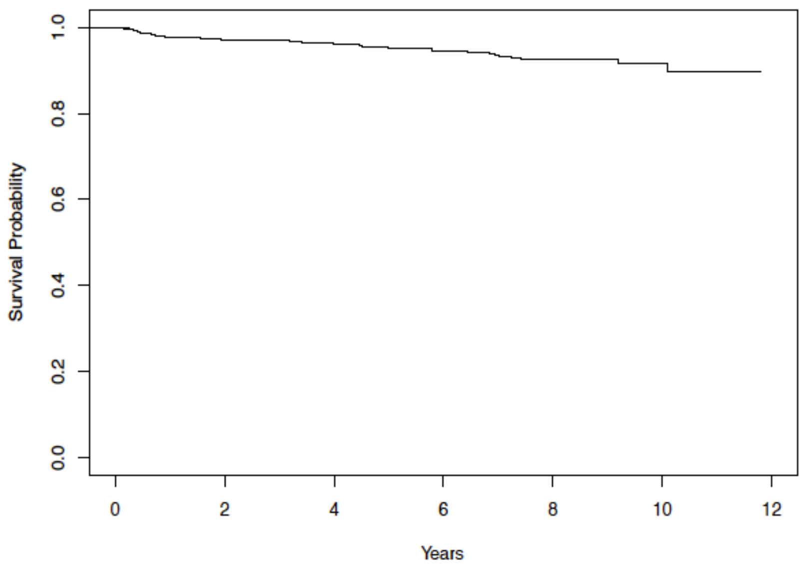

Figure 2. Univariable Kaplan-Meier Analysis of implant survival over time.

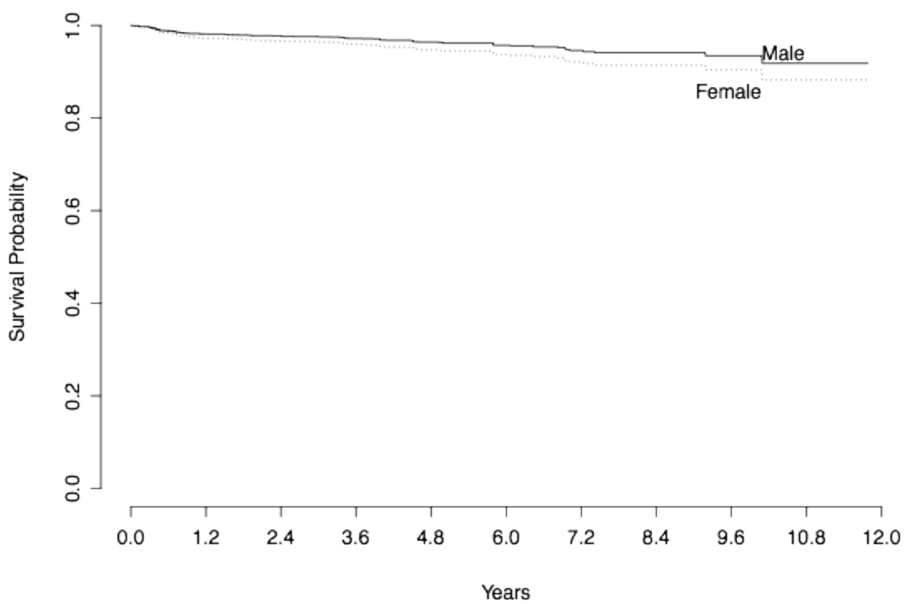

Figure 3. Estimated survival plot for gender.

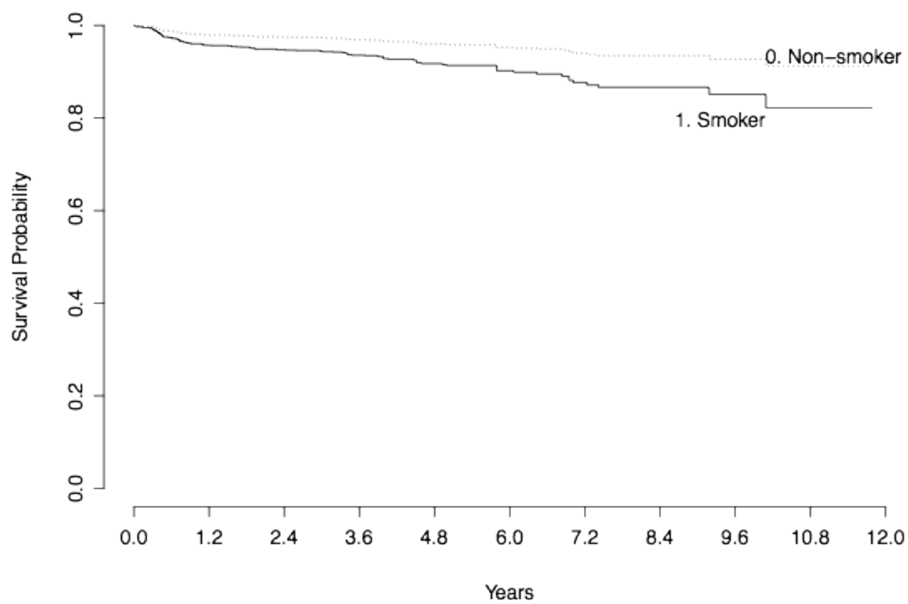

Figure 4. Estimated survival plot for smoking

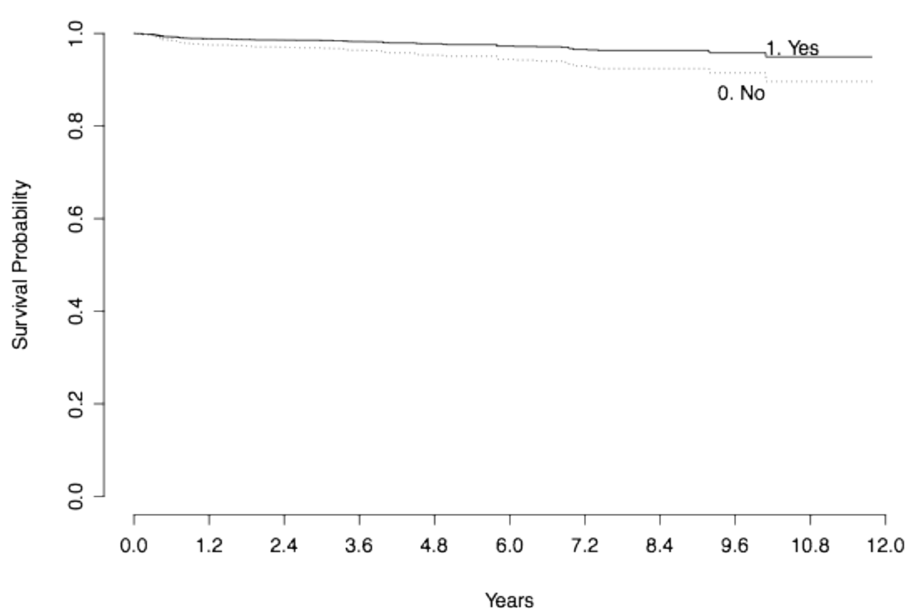

Figure 5. Estimated survival plot for patients with and without diabetes.

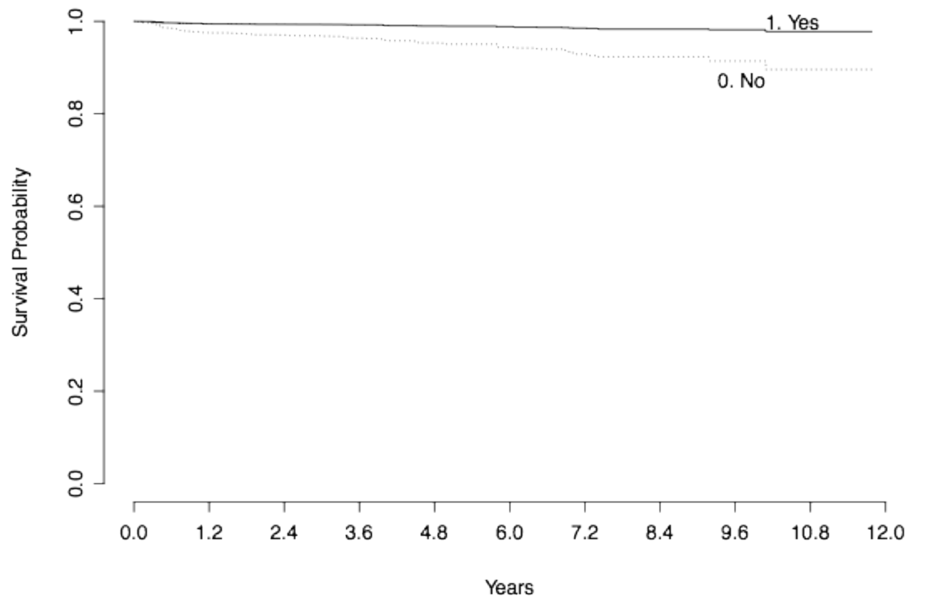

Figure 6. Estimated survival plot for patients with and without bisphosphonates.

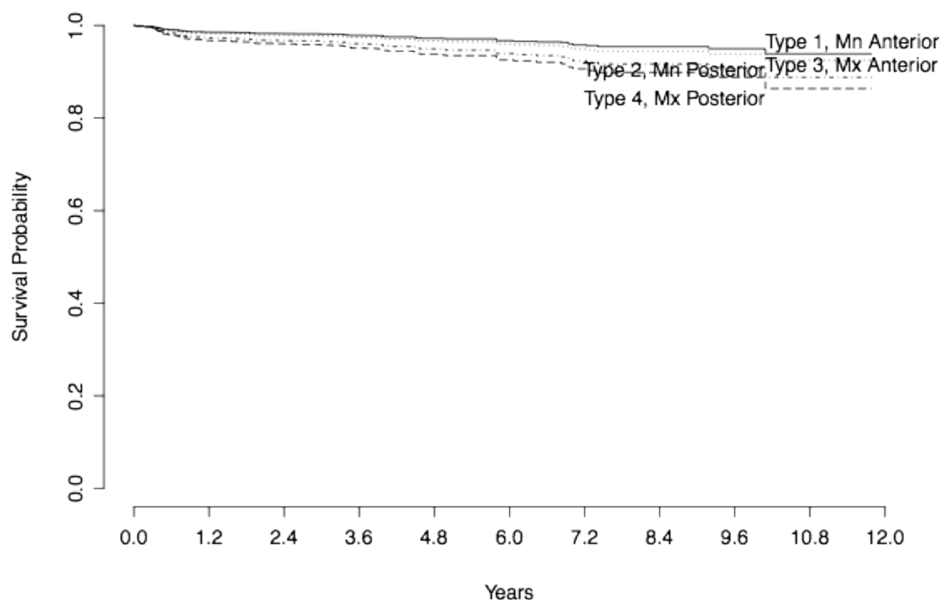

Figure 7. Estimated survival plot for implants by jaw region.

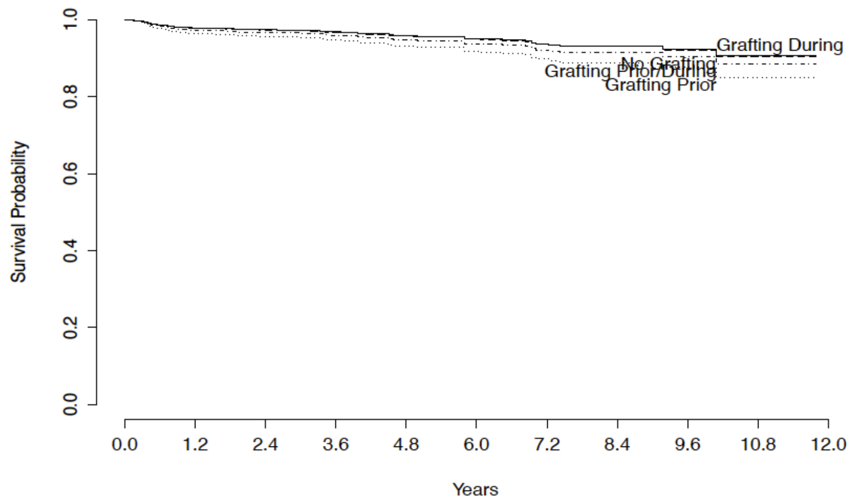

Figure 8. Estimated survival plot for implants by bone grafting prior to and during implant placement.

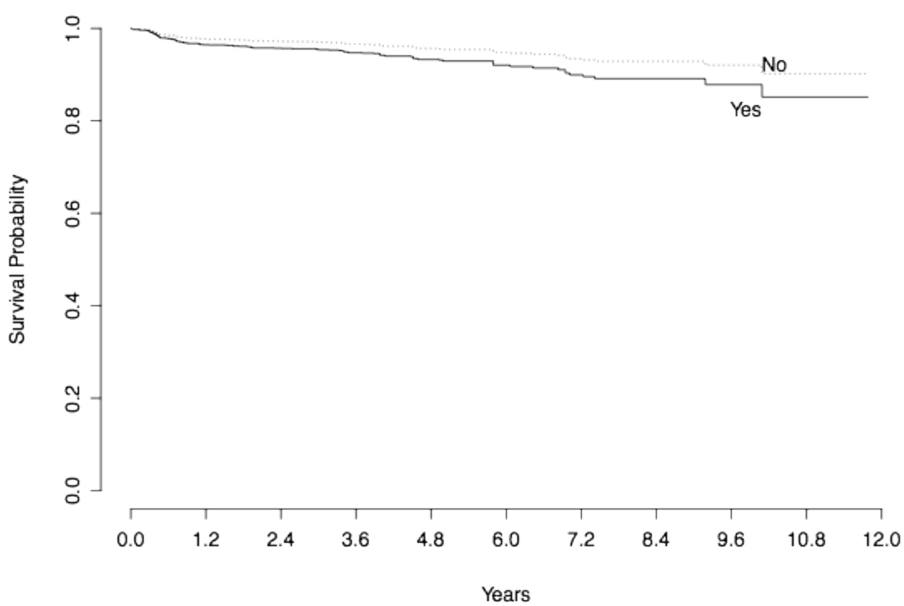

Figure 9. Estimated survival plot for implants by sinus grafting prior to implant placement.

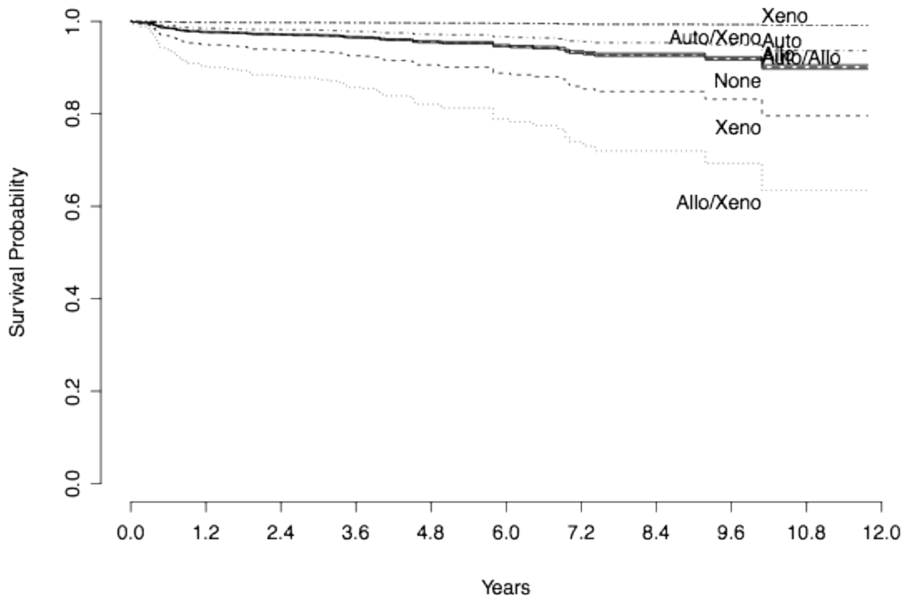

Figure 10. Estimated survival plot for implants by bone grafting at time of implant placement.

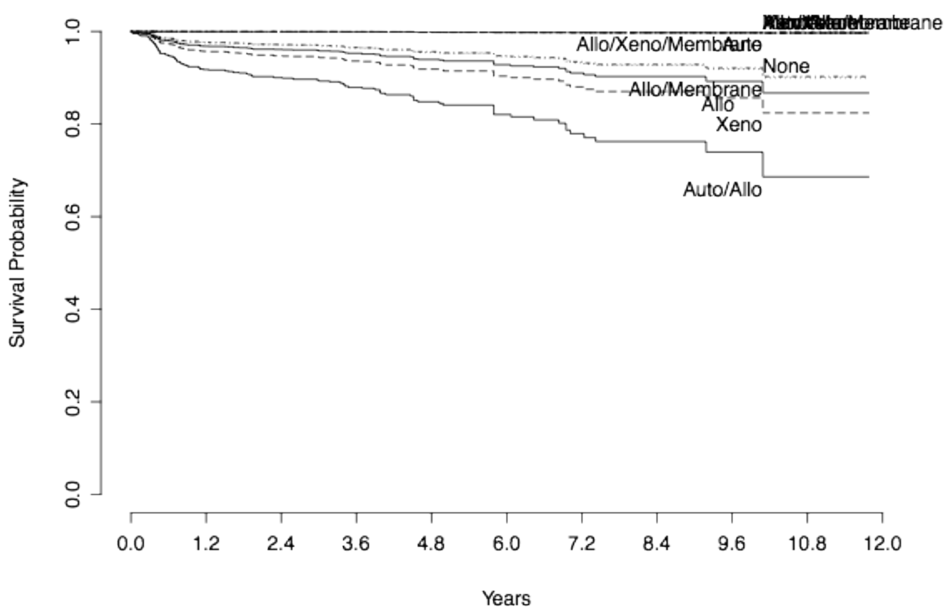

Figure 11. Estimated survival plot for implants by type of sinus grafting material.

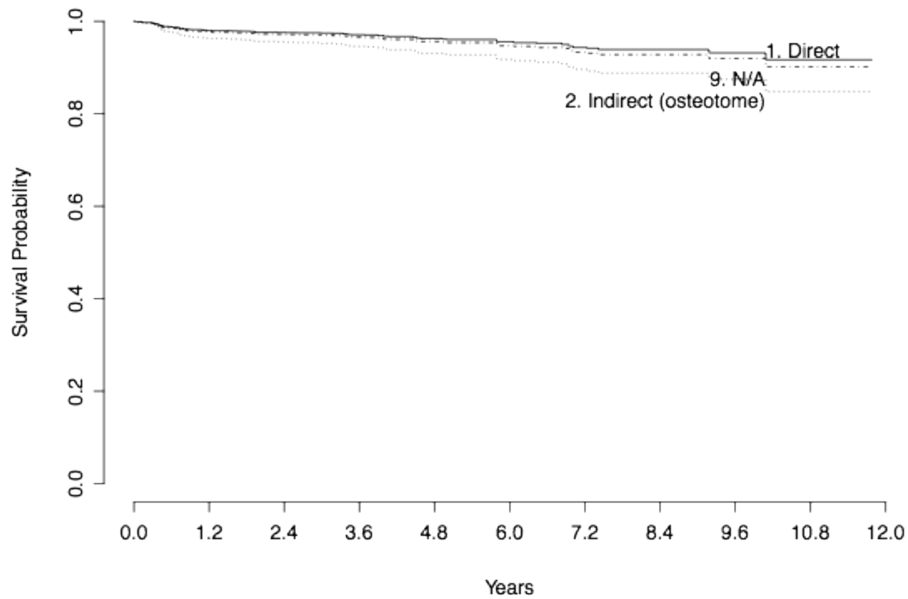

Figure 12. Estimated survival plot for implants by sinus grafting at time of implant placement.

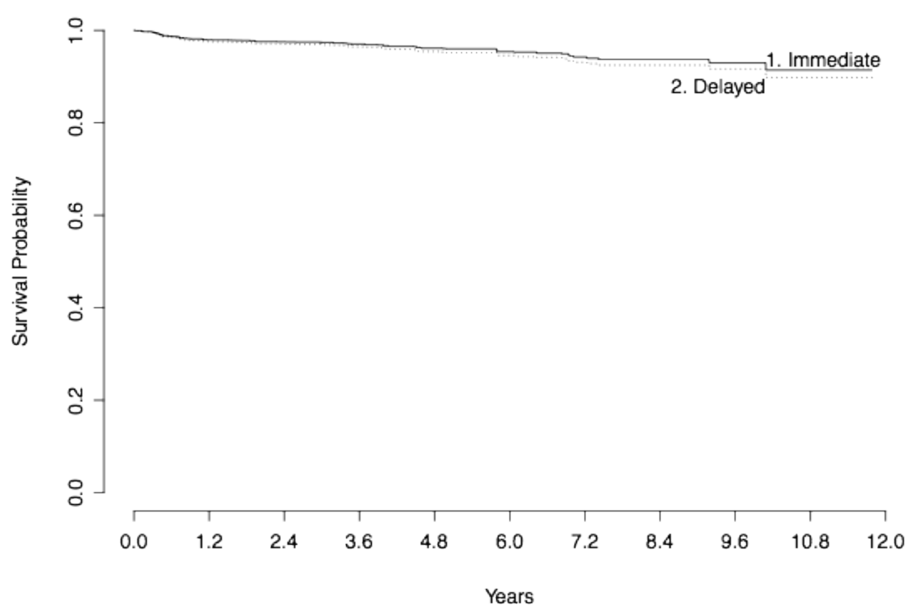

Figure 13. Estimated survival plot for implants by immediate versus delayed placement.

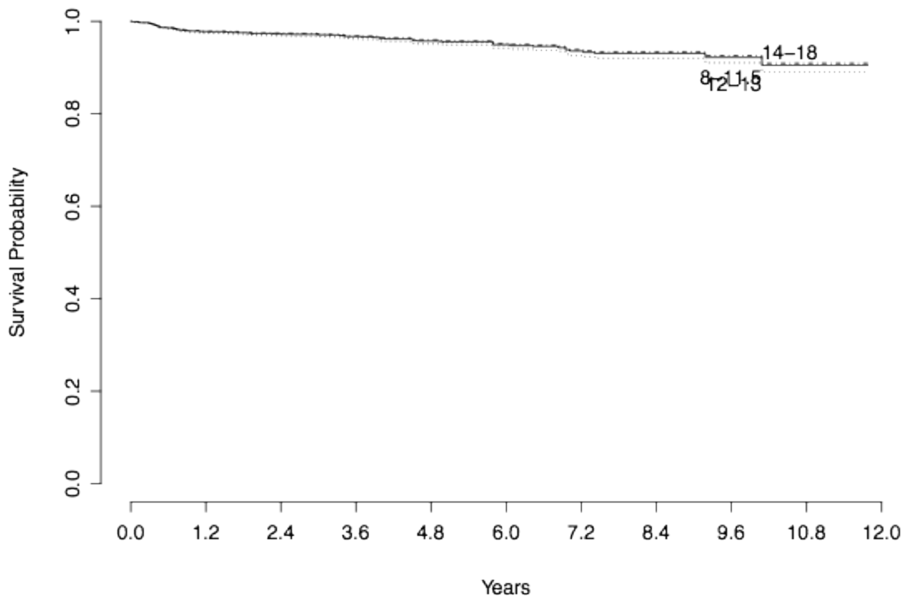

Figure 14. Estimated survival plot for implants by implant length.

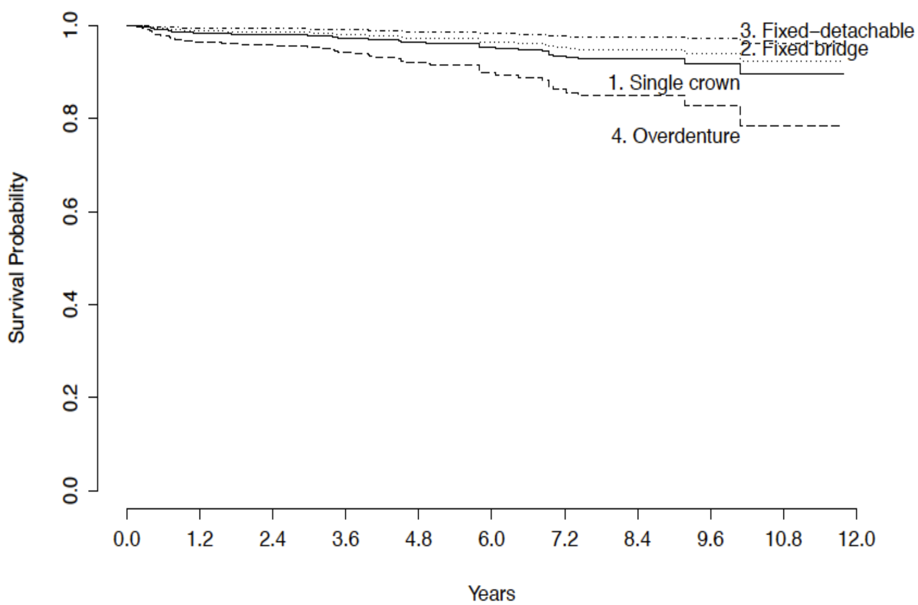

Figure 15. Estimated survival plot for implants by type of restoration.