Survival of Dental Implants Placed in Grafted and Nongrafted Bone: A Retrospective Study in a University Setting

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Purpose: *To compare dental implant survival rates when placed in native bone and grafted sites. Additionally, risk factors associated with dental implant loss were identified. This study was based on the hypothesis that bone grafting has no effect on implant survival rates.* ***Materials and Methods:*** *A retrospective chart review was conducted for patients receiving dental implants at the University of Texas, School of Dentistry from 1985 to 2012. Exclusion criteria included patients with genetic diseases, radiation and chemotherapy, or an age less than 18 years. To avoid misclassification bias, implants were excluded if bone grafts were only done at the same time of placement. Data on age, sex, tobacco use, diabetes, osteoporosis, anatomical location of the implant, implant length and width, bone graft, and professional maintenance were collected for analysis.* ***Results:*** *A total of 1,222 patients with 2,729 implants were included. The cumulative survival rates at 5 and 10 years were 92% and 87% for implants placed in native bone and 90% and 79% for implants placed in grafted bone, respectively. The results from multivariate analysis (Cox regression) indicated no significant difference in survival between the two groups; having maintenance therapy after implant placement reduced the failure rate by 80% (P < .001), and using tobacco increased the failure rate by 2.6-fold (P = .001).* ***Conclusion:*** *There was no difference in the dental implant survival rate when implants were placed in native bone or bone-grafted sites. Smoking and lack of professional maintenance were significantly related to increased implant loss.* Int J Oral Maxillofac Implants 2016;31:310–317. doi: 10.11607/jomi.4681

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Dental implant failure is determined when the performance of the implant falls below a particular level and can no longer stay in the mouth.[1,2] Failures can be biologic, mechanical, iatrogenic, or due to insufficient patient adaptation.[3,4] Biologic implant failures are classified as early (or primary) and late (or secondary). If the failure occurs before or at the time of the abutment connection, it is considered an early failure; if it arises after occlusal loading, it is a late failure.[5,6]

Currently, a predominant challenge for successful dental rehabilitation with dental implants is the amount of available bone.[7] Advanced atrophy of the alveolar ridge impairs the insertion of dental implants, and therefore, restoration of the dental masticatory system.[8] At sites with severe atrophy, bone augmentation may be necessary to provide sufficient stability for the implant. Various augmentation techniques can be performed before or in conjunction with dental implant placement, including the application of autogenous bone graft, allogeneic bone grafts, or synthetic materials.[9]

A highly controversial issue is whether implant survival rates are higher in augmented sites versus nonaugmented sites. A study by Sbordone and colleagues reported a dental implant survival rate of 98.9% in native bone as compared with 99.1% in

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bone-grafted sites.[10] On the other hand, Sesma and colleagues reported a significant association between dental implant failure and the presence of a previous bone graft placement at the implant area.[11] Jung and colleagues reported a survival rate of 91.9% to 92.6% after a 12-year follow-up period for implants placed after guided bone regeneration procedures.[12]

Similarly, in cases of reduced maxillary bone height, a sinus augmentation procedure may be required before dental implants can be placed.[13,14] Several investigators compared implant survival after sinus augmentation procedures in the posterior maxilla with implant survival in nongrafted sites.[15] Graziani and colleagues in 2004 reported greater variability with regard to survival in grafted sinuses. Indeed, the results of some studies showed that this procedure might decrease the survival rate of dental implants.[16] Del Fabbro and colleagues conducted a systematic review of implant survival rates in grafted sinuses; they reported implant survival rates between 93.7% and 97.2% after a minimum of 3 years.[17] Tong and colleagues conducted a meta-analysis, the results of which showed implant survival rates of 87% to 98% in augmented sinuses over a follow-up period of 6 to 60 months.[18]

In light of mixed results on implant survival rates placed in native bone as compared with grafted sites, the aim of this study was to compare the survival rates of implants placed in native bone versus bone-grafted sites, and identify risk factors associated with implant failure. This study was based on the hypothesis that there was no statistically significant difference in dental implant survival rates when placed in native bone as compared with grafted bone.

MATERIALS AND METHODS

Study Design

This study was approved by the Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston (UTSOD; HSC-DB-13-0786). A retrospective chart review was conducted including all patients who received dental implants at the UTSOD spanning from January 1, 1985, to December 31, 2012. All dental implants placed in the university were documented either in the electronic health record (AxiUm, Exan Group, Canada) or physical dental charts retained by the university.

Exclusion criteria included patients who presented with any of the following conditions: genetic diseases affecting bone metabolism, radiation, and chemotherapy for treatment of head and neck cancer. Subjects below 18 years of age were excluded per the American Academy of Periodontology guidelines.[19] To avoid misclassification bias, implants were excluded from the analysis if bone grafting was performed only in conjunction with implant placement. Narrow implants (< 3 mm), short implants (< 5 mm), or implants placed in sites of previously failed implants were also excluded due to evidence of lower survival rates that could skew the results of this study.[20,21]

The sample size was calculated to compare the survival rate of dental implants placed in grafted versus native bone sites using previously reported data. The sample size calculation with a significance level set at .05 (two-sided test), power of 0.8, standard deviation of 0.4, found that inclusion of 1,488 implants was needed, assuming dental implant loss of 2.4% according to Sesma et al,[11] and proportion of withdrawals of 40.8% according to Krebs et al.[22]

Clinical Procedures

All bone augmentation procedures and placement of the endosseous dental implants were performed at the UTSOD by postdoctoral residents participating in the surgical advanced education programs of oral and maxillofacial surgery or periodontics under the direct supervision of faculty with similar advanced education training, as well as performed by faculty with specialty training in oral maxillofacial surgery or periodontics. The test group included endosseous implants placed at sites with previous bone augmentation. Implants placed at sites that required bone augmentation at the time of implant placement only were not included in either the test or control groups. The bone augmentation procedures included in this analysis included all guided bone regeneration procedures (treating Seibert Class I, II, and III-type defects), sinus augmentations, and socket/ridge preservation techniques with bone replacement grafts including autografts, allografts, alloplasts, and xenografts. At least 3 months of healing was documented before implant surgery was performed at these sites. The ratio of grafted to native bone that the endosseous implants were eventually placed in was not measured in any of the patient charts and could not be calculated. The control group included endosseous implants placed exclusively in native bone.

The endosseous implant surgeries were performed in the UTSOD clinics utilizing the drill sequences recommended by the implant manufacturers. Implants were placed during the timeframe of 1985 to 2012. All dental implant systems approved by UTSOD were included in this study. The implant type, shape, and surface characteristics varied

with the different manufacturers. Over the span of this study, advances in implant surface technology and implant-to-abutment connection designs provided changes in the endosseous implants that were placed at the institution. The specific implant design or surface characteristics of the implants were not considered in this study. Additionally, implant surgical and loading protocols evolved over the span of this retrospective study. Implants placed during the 1980s and early 1990s followed a submerged protocol allowing at least 3 months of healing before attachment of a healing abutment or a definitive restorative prosthesis. With emerging evidence supporting a "one stage" approach to implant placement, healing abutment attachment at the time of implant placement was incorporated into the surgical protocol for those implants achieving insertion torque values equal to or greater than 35 Ncm. The specific surgical protocol, ie, the two-stage or one-stage approach, was not considered in this study.

Loading protocols, whether immediate, early, or conventional (also known as "delayed"), were not clearly delineated in the patient charts. In a 2014 meta-analysis published by Su et al, no significant differences were found in the success rates of implants restored under the immediate, early, or conventional loading protocols.[23] The specific loading protocol utilized in restoring the implants, ie, immediate, early, or conventional, was not considered in this study.

All dental implants that were removed due to implant fracture, mobility, or nontreatable recurrent peri-implant infections were recorded as failures.

Study Variables

For the purpose of this application and given the difficulty of obtaining additional data such as bone loss and implant mobility, implant failure was defined as the absence of the dental implant at any point in time after its insertion. Dental implant failure was considered the outcome variable as determined by its presence or absence in the oral cavity at the time of data collection. Patient records were followed until the last visit of the participant to the clinic, and follow-up time was defined as the time from placement to failure, to last follow-up, or to the end of the follow-up period, whichever happened first.

Documentation was made as to whether the dental implants were placed in native bone or at grafted sites. Given that the primary outcome was dental implant presence or absence in the oral cavity, covariates were examined as possible confounders to implant survival, as reported in the literature.[12,22,24–27] The extracted data contained: self-reported demographics including patient age, sex, self-reported tobacco smoking (tobacco users, nonusers), diabetes mellitus (yes/no), and osteoporosis (yes/no), bone graft (yes/no), implant location (maxilla, mandible, anterior, posterior), implant length and width, and maintenance compliance (yes/no).

Data Extraction

Data were extracted from electronic patient dental records by a script developed by the Informatics Department at UTSOD. The script was validated by randomly selecting 50 charts for manual review. Additionally, four dentists and a dental student manually reviewed clinical notes from the charts to extract information about bone augmentation, implant length and width, and implant removal, which was partly extracted by the script. Data from paper charts were manually extracted by three dentists. All reviewers participated in a comprehensive training and calibration period. Since a patient may have had multiple implants placed, an implant was sampled as a unit that was entered once into the dataset and considered a single observation.

Data Analysis

Kappa statistics were calculated for agreement between each reviewer and a reference reviewer. Characteristics of subjects and implants are presented as a mean, standard deviation, and range. Frequency counts and percentages are presented for categorical data. Cumulative survival rates were calculated using the Kaplan-Meier method. The difference between survival curves was tested using the log-rank test.

Univariate analyses using the log-rank test were performed for each covariate to identify its association with implant survival. Covariates were selected for multivariate analysis if they had a P value $\leq .25$. A multivariable analysis using a Cox proportional-hazards regression model that was modified for correlated dependent observations[28] was used to compare implant survival for native bone vs grafted sites, correcting for confounding factors. The multivariate analysis was restricted to patients for whom data on covariates included in the proportional-hazards model were available. The results from the proportional-hazards regression are presented as P values, hazard ratio (HR), and 95% confidence interval (CI). The level of significance was set at 5%. STATA software (version 13)[29] was used for statistical analysis.

Table 1a Patient-Related Characteristics for Patients Receiving Dental Implants at the Dental Clinic from 1985 to 2012 (n = 1,222 patients, 2,729 implants)

Patient-related characteristics	No. (%) or mean ± SD (range)
Age at first implant placement (y)	55.2 ± 14.6 (18– 87)
Sex	
Male	518 (42.4)
Female	704 (57.6)
Diabetes	
No	1,084 (90.5)
Yes	114 (9.5)
Osteoporosis	
No	873 (92.5)
Yes	71 (7.5)
Tobacco smoker	
No	975 (81.9)
Yes	215 (18.1)

Table 1b Implant-Related Characteristics for Patients Receiving Dental Implants at the Dental Clinic from 1985 to 2012 (n = 1,222 patients, 2,729 implants)

Implant-related characteristics	No. (%) or mean ± SD (range)
Anatomical location of implant	
Posterior mandible	990 (36.3)
Anterior mandible	526 (19.3)
Anterior maxilla	406 (14.9)
Posterior maxilla	807 (29.5)
Implant diameter (mm)	4.2 ± 0.6 (3– 6.5)
Implant length (mm)	11.7 ± 2 (5–20)
Bone graft augmentation	
No	1,767 (64.7)
Yes	953 (35.3)
Implant present	
No	166 (6.1)
Yes	2,563 (93.9)
Maintenance	
No	1,569 (57.5)
Yes	1,160 (42.5)

RESULTS

Characteristics of Patients and Implants

All reviewers had highly reliable agreement with the reference reviewer (Kappa scores > 0.8). Patient- and implant-related characteristics are presented in Table 1. A total of 1,222 patients with 2,729 implants were included in the analysis. The number of implants per patient ranged from 1 to 14 with a median of 2. The percentage of patients who received one, two, three, four, and more than four implants were 45%, 28%, 10%, 8%, and 9%, respectively. Two-thirds of the implants were placed in native bone with the other one-third placed at augmented sites. The follow-up time ranged from 0.2 months to 16.8 years (201.5 months) with a median of 20.3 months during which 6% of the implants were removed. At the patient level, 9% of the patients experienced implant failure ranging from 1 to 8 implants per individual with a median of 1. Among those with failed implants, 71%, 18%, 6%, and 3% lost one, two, three, and four implants, respectively; and 2% lost more than five implants.

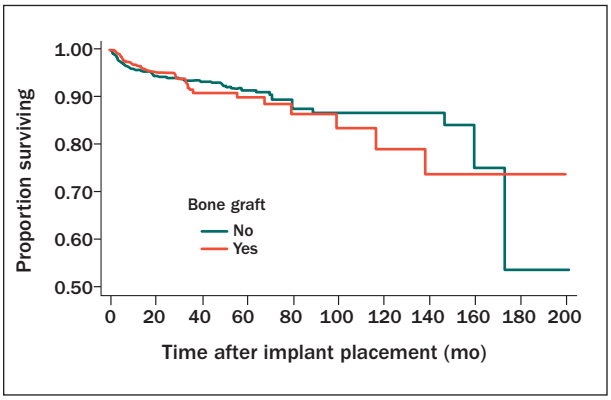
Survival Rates and Risk Factors of Implant Failure

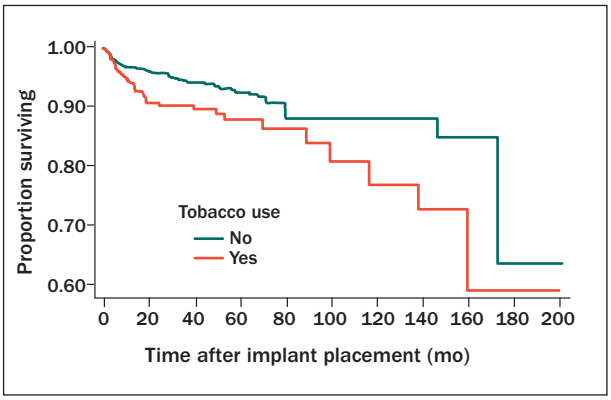
Cumulative survival rates at 5 and 10 years were 92% and 87% for implants placed in native bone, and 90% and 79% for implants placed in grafted bone, respectively (Table 2). As shown in Fig 1, Kaplan-Meier survival curves for implants placed in native and grafted bone crossed several times and were close to each other from placement to approximately 100 months. After that, the curve for native bone stayed above the curve for grafted bone until approximately 175 months, when it crossed and went below it. However, the log-rank test showed that there was no significant difference in survival between the two groups ($P = .53$).

Univariate analysis showed that implant failure was significantly associated with tobacco use and professional maintenance but not associated with bone augmentation and the remaining variables (Table 3). The survival curves for nonsmoking and having maintenance care were higher than the curves for smoking and not having maintenance care at every time point, respectively (Figs 2 and 3). Multivariate analysis using Cox's regression model showed that these two variables were significantly associated with implant failure (Table 4). Participating in professional maintenance after implant placement reduced the implant failure rate by 80% (HR = 0.2, $P < .001$). Additionally, self-reported cigarette smokers increased their implant failure rate by 2.6 times compared to nonsmokers (HR = 2.6, $P < .001$). No interaction terms were significant.

Table 2 Survival Rate of Implants Placed in Native vs Grafted Bone at the Dental Clinic from 1985 to 2012

	Native bone			Grafted bone		
Time (mo)	Total no. of implants	No. of failures	Cumulative surviving (95% CI)	Total no. of implants	No. of failures	Cumulative surviving (95% CI)
6	1,480	49	0.97 (0.96, 0.98)	796	19	0.98 (0.97, 0.99)
12	1,217	18	0.96 (0.95, 0.97)	664	8	0.97 (0.95, 0.98)
24	807	15	0.94 (0.93, 0.95)	412	9	0.95 (0.93, 0.97)
36	584	6	0.94 (0.92, 0.95)	251	12	0.92 (0.89, 0.94)
48	393	2	0.93 (0.92, 0.95)	133	2	0.91 (0.88, 0.93)
60	244	6	0.92 (0.89, 0.93)	80	1	0.9 (0.86, 0.93)
120	44	8	0.87 (0.82, 0.9)	19	4	0.79 (0.65, 0.88)
180	7	6	0.54 (0.25, 0.75)	10	1	0.74 (0.56, 0.85)





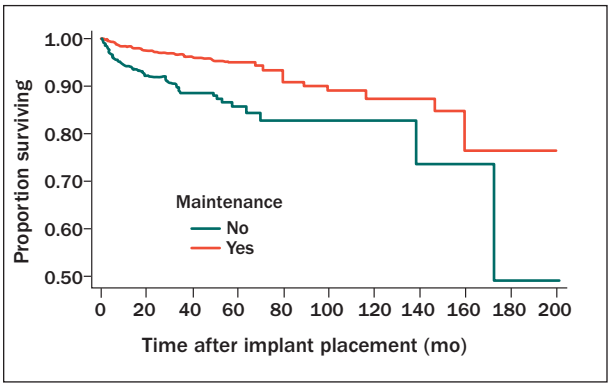


Fig 1 *(above left)* Kaplan-Meier survival curves for implants placed in native and grafted bone (log-rank test = 0.02, *df* = 1; *P* = .9).

Fig 2 *(above right)* Kaplan-Meier survival curves for implants of tobacco users and nonusers (log-rank test = 13, *df* = 1; *P* < .001).

Fig 3 *(left)* Kaplan-Meier survival curves for implants with and without professional maintenance (log-rank test = 39.6, *df* = 1; *P* < .001).

Table 3 Univariate Analyses for Factors Associated with Implant Failure

Characteristics	*P*
Sex	.09
Diabetes	.07
Osteoporosis	.53
Tobacco smoker	< .001
Anatomical location of implant	.55
Implant diameter (mm)	.57
Implant length (mm)	.21
Bone graft augmentation	.9
Maintenance	< .001

Table 4 Multivariate Analyses for Factors Associated with Implant Failure

Characteristics	Hazard ratio	95% CI	*P*
Tobacco smoker			
No	1.0		
Yes	2.6	1.5–4.6	.001
Maintenance			
No	1.0		
Yes	0.2	0.1–0.3	< .001

DISCUSSION

Risk factors related to implant loss include presence of periodontal disease, lack of dental implant maintenance, smoking, diabetes, as well as other factors. The impact of augmenting atrophic alveolar ridges, either prior to or at the time of implant placement, on implant survival is limited and controversial.[11,14,30,31]

In this study, over a 15-year period, comparison of the cumulative survival rates of implants placed in alveolar ridges augmented via bone-grafting procedures with the cumulative survival rates of implants placed in native alveolar ridges found no statistically significant differences ($P = .9$). The cumulative survival rate is the probability that an implant would survive to a particular time point. Ninety percent or better cumulative survival rates were found for all implants up to almost 100 months after placement. The quantity of implants remaining in the study beyond 10 years dropped dramatically, which influenced the reported cumulative survival rates, resulting in a reduced probability of implant survival, ie, 54% for the native bone group and 74% for the grafted sites group. In total, the number of implants that failed over the span of the study amounted to 110 out of a total of 1,767 implants placed in native bone, yielding a failure percentage of 6.2%, or a survival of 93.8% of all implants placed. Similarly, implants placed in grafted bone sites were found to have 56 failed implants out of a total of 953 placed implants, yielding a percent of failures of 5.9%, or a survival of 94.1% of all implants placed.

There have been few studies published that have made direct comparisons of survival rates of implants placed in grafted versus native bone. The results have been contradictory and often affected by various limitations. A systematic review[14] and three retrospective studies[10,30,32] found no difference between the survival of implants placed in native or augmented bone, which corroborated the results of this study. However, these four studies limited the comparison to the posterior maxilla, whereas the present study included implants placed in all locations of the maxilla and mandible. Design limitations associated with these studies may reduce the impact of their findings: *(1)* lack of appropriate statistical methods to compare the two groups,[14] *(2)* no control for the effect of cofactors such as smoking and professional maintenance, *(3)* lack of appropriate analyses to address the issue of correlated data for multiple implants per patient,[10,30] *(4)* small sample size, *(5)* short follow-up time, and *(6)* lack of accountability for follow-up time in their data analysis.[10] Compared with these studies, the present study had a large sample size, long follow-up time, controlled for the effects of cofactors, correlated data, and accounted for follow-up time.

Other studies found differences in the survival rates of implants placed in grafted sites as compared with native bone.[11,31,33] Sesma et al[11] published a study evaluating survival of 988 dual acid-etched implants placed in native bone, after sinus augmentation, or after autogenous block bone-grafting procedures. After following implant survival up to 6 years postplacement, the authors found a significant association between dental implant failure and the presence of bone graft in the implant area. While the implant failure rate was greater at bone-grafted sites, the confidence intervals associated with the failure rates were large, indicating low precision of the results, possibly related to the limited number of implant failures. In addition, the study did not control for professional maintenance, which was found to be a critical factor associated with implant survival. Finally, due to the specificity of the implant design and augmentation procedures outlined by Sesma et al,[11] the results could not be applied to other types of implants and bone augmentation therapies.

Contrary to the results of the aforementioned studies, two studies found higher implant success rates for implants placed in the grafted maxillary sinuses compared with implants placed at nongrafted posterior maxilla sites.[31,33] Olson et al explained that their results could be attributed to the use of longer implants in the grafted sites.[31] Shortcomings of these studies included insufficient follow-up time, sample size to allow necessary statistical analyses,[33] and lack of control for confounders.

Smoking has been well-established as a risk factor for periodontitis and as the second strongest of the modifiable risk factors, the first being bacterial plaque.[34] Results from the present study on dental implant failure in individuals who smoke cigarettes are in agreement with previous researchers who described that implants placed in individuals who smoke cigarettes had a twofold increase in failure rates, independent of a variety of implant designs and surfaces.[35] The number of cigarettes smoked daily has been shown to influence implant survival. A study by Sánchez-Pérez et al[36] classified individuals according to the number of cigarettes smoked as light, moderate, or heavy smokers. They found that the success rates were 84% for smokers as compared with 98.6% for nonsmokers. They also found that among smokers, heavy smokers had more than twice the risk for implant failure than light or moderate smokers. In the present study, a potential limitation was that the amount of tobacco smoking was a self-reported event subject to recall bias, which could have affected the implant failure rates; nevertheless, a significant association was found between implant failure and tobacco smoking, consistent with the literature.

Maintenance of implant restorations is crucial because most causes of implant failure, after placement, can be identified, corrected, or prevented by a regular maintenance program and monitoring of the dental implant. Costa et al followed patients who received dental implants over a 5-year period. They reported an incidence of periimplantitis in 18% of the patients who participated in

preventive maintenance, whereas in the group without preventive maintenance, 43.9% of the patients were diagnosed with peri-implantitis.[37] Recent publications have identified remnants of cement attached to the abutment-implant surface as a risk factor for peri-mucositis and peri-implantitis.[38,39] Radiographs taken at maintenance visits could help identify the presence of excess cement and allow elimination of this plaque-retaining accretion. Since this retrospective study did not evaluate radiographs in the course of the analysis, it is not known if cement remnants contributed to the reported implant failures. Current approaches to implant maintenance are somewhat haphazard and not standardized, with several authors[40–44] recommending maintenance visits every 3 to 4 months for the first year after implant placement. The interval between maintenance visits should be determined after evaluating the initial patient response to periodontal therapy and modified according to the periodontal and dental implant health status.

The long-term outcome of implant therapy can be affected by local or systemic diseases or other compromising factors; in fact, it has been suggested that some local and systemic factors could represent contraindications to dental implant treatment. Osteoporosis is the most studied bone-related disease. When evaluating whether dental implants in osteoporotic patients had a different long-term outcome, a systematic review revealed no association between systemic bone mineral density status and implant loss, concluding that the use of dental implants in osteoporosis patients was not contraindicated.[25] In a cross-sectional study, no relation was found between osteoporosis and peri-implantitis, and even patients with severe osteoporosis have been successfully rehabilitated with implant-supported prostheses.[45]

An additional risk factor associated with implant failure due to lack of osseointegration is uncontrolled diabetes mellitus. Current literature has shown that dental implants in diabetic patients with good metabolic control have similar success rates when compared with age-matched healthy controls.[46–49] In a systematic literature search including 18 studies published up to 2009, the authors concluded that poorly controlled diabetes negatively affects implant osseointegration.[50] This fact is consistent with the known effects of hyperglycemic states on impaired immunity, microvascular complications, and/or osteoporosis. According to Busenlechner et al, well-controlled patients diagnosed with diabetes demonstrated high long-term survival rates of 95.1% that did not significantly differ from the healthy population.[51] The present results agreed with the previous publications.

The findings in this study were subject to some limitations; first, some information was not consistently or completely recorded in the dental records, such as the amount of native bone present before a bone-graft procedure was performed, quantity and frequency of tobacco use, medications for diabetes, and osteoporosis. Also, patients' self-report of tobacco use and medical conditions might be subject to recall bias. Patients might also have professional maintenance at private dental clinics, which was not documented in the dental school patient records. Another concern was that some patients did not return for further appointments, so the survival rate of dental implants in missing patients was unknown. Additionally, the confounding effects of periodontal status and oral hygiene practices, which might affect implant survival, were not controlled in this study. However, the effect of these factors on the bias would be minimized due to the standard of care for dental school patients, whereby prior periodontal disease treatment, with confirmed good oral hygiene practices, was established before implant placement. In addition, multiple types of prosthetic restorations were fabricated for the dental implants, which were not controlled in this study because many failures happen before implant loading. Several lines of evidence remain controversial in this topic, and more research is needed to clarify treatment implications.

CONCLUSIONS

There was no difference in the dental implant survival rate when implants were placed in native bone or bone-grafted sites. Tobacco use and lack of professional maintenance were statistically significantly related to increased implant loss.

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REFERENCES

1. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. Eur J Oral Sci 1998;1:527–551.
2. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (II). Etiopathogenesis. Eur J Oral Sci 1998;3:721–764.
3. Skalak R. Aspects of biomechanical considerations. In: Brånemark P, Zarb G, Albrektsson T, eds. Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:117–128.
4. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986; 1:11–25.

5. Alsaadi G, Quirynen M, Michiles K, et al. Impact of local and systemic factors on the incidence of failures up to abutment connection with modified surface oral implants. J Clin Periodontol 2008;1:51–57.
6. Smith DE, Zarb GA. Criteria for success of osseointegrated endosseous implants. J Prosthet Dent 1989;5:567–572.
7. Van Steenberghe D, Lekholm U, Bolender C, et al. Applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: A prospective multicenter study on 558 fixtures. Int J Oral Maxillofac Implants 1990;3:272–281.
8. Sennerby L, Roos J. Surgical determinants of clinical success of osseointegrated oral implants: A review of the literature. Int J Prosthodont 1998;5:408–420.
9. Clementini M, Morlupi A, Agrestini C, Barlattani A. Immediate versus delayed positioning of dental implants in guided bone regeneration or onlay graft regenerated areas: A systematic review. Int J Oral Maxillofac Surg 2013;5:643–650.
10. Sbordone L, Toti P, Menchini-Fabris G, Sbordone C, Guidetti F. Implant survival in maxillary and mandibular osseous onlay grafts and native bone: A 3-year clinical and computerized tomographic follow-up. Int J Oral Maxillofac Implants 2009;4:695–703.
11. Sesma N, Pannuti C, Cardaropoli G. Retrospective clinical study of 988 dual acid-etched implants placed in grafted and native bone for single-tooth replacement. Int J Oral Maxillofac Implants 2012;5:1243–1248.
12. Jung RE, Fenner N, Hämmerle CH, Zitzmann NU. Long-term outcome of implants placed with guided bone regeneration (GBR) using resorbable and non-resorbable membranes after 12-14 years. Clin Oral Implants Res 2013;10:1065–1073.
13. Buser DA, Tonetti M. Clinical trials on implants in regenerated bone. Ann Periodontol 1997;1:329–342.
14. Wallace SS, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. Ann Periodontol 2003;1:328–343.
15. Roos-Jansåker AM, Lindahl C, Renvert H, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part I: Implant loss and associations to various factors. J Clin Periodontol 2006;4:283–289.
16. Graziani F, Donos N, Needleman I, Gabriele M, Tonetti M. Comparison of implant survival following sinus floor augmentation procedures with implants placed in pristine posterior maxillary bone: A systematic review. Clin Oral Implants Res 2004;6:677–682.
17. Del Fabbro M, Wallace SS, Testori T. Long-term implant survival in the grafted maxillary sinus: A systematic review. Int J Periodontics Restorative Dent 2013;6:773–783.
18. Tong DC, Rioux K, Drangsholt M, Beirne OR. A review of survival rates for implants placed in grafted maxillary sinuses using meta-analysis. Int J Oral Maxillofac Implants 1998;2:175–182.
19. Iacono VJ. Dental implants in periodontal therapy. J Periodontol 2000;12:1934–1942.
20. Quaranta A, Perrotti V, Piattelli A, Piemontese M, Procaccini M. Implants placed in sites of previously failed implants: A systematic review. Implant Dent 2014;3:311–318.
21. Winkler S, Morris HF, Ochi S. Implant survival to 36 months as related to length and diameter. Ann Periodontol 2000;1:22–31.
22. Krebs M, Schmenger K, Neumann K, et al. Long-term evaluation of ANKYLOS dental implants, part I: 20-year life table analysis of a longitudinal study of more than 12,500 implants. Clin Implant Dent Relat Res 2015;17(suppl 1):275–286.
23. Su M, Shi B, Zhu Y, et al. Comparison of implant success rates with different loading protocols: A meta-analysis. Int J Oral Maxillofac Implants 2014;2:344–352.
24. Vervaeke S, Collaert B, Cosyn J, Deschepper E, De Bruyn H. A multifactorial analysis to identify predictors of implant failure and peri-implant bone loss. Clin Implant Dent Relat Res 2015; (suppl 1):298–307.
25. Geckili O, Bilhan H, Geckili E, et al. Evaluation of possible prognostic factors for the success, survival, and failure of dental implants. Implant Dent 2014;1:44–50.
26. Chen H, Liu N, Xu X, Qu X, Lu E. Smoking, radiotherapy, diabetes and osteoporosis as risk factors for dental implant failure: A meta-analysis. PLoS One 2013;8:e71955.
27. Herrmann I, Lekholm U, Holm S, Kultje C. Evaluation of patient and implant characteristics as potential prognostic factors for oral implant failures. Int J Oral Maxillofac Implants 2005;2:220–230.
28. Chuang SK, Cai T. Predicting clustered dental implant survival using frailty methods. J Dent Res 2006;12:1147–1151.
29. StataCorp. Stata Statistical Software: Release 13. College Station, Texas: StataCorp LP; 2013.
30. Pabst AM, Walter C, Ehbauer S, et al. Analysis of implant-failure predictors in the posterior maxilla: A retrospective study of 1395 implants. J Craniomaxillofac Surg 2015;3:414–420.
31. Olson JW, Dent CD, Morris HF, Ochi S. Long-term assessment (5 to 71 months) of endosseous dental implants placed in the augmented maxillary sinus. Ann Periodontol 2000;1:152–156.
32. Huynh-Ba G, Friedberg JR, Vogiatzi D, Ioannidou E. Implant failure predictors in the posterior maxilla: A retrospective study of 273 consecutive implants. J Periodontol 2008;12:2256–2261.
33. Lozada JL, Emanuelli S, James RA, Boskovic M, Lindsted K. Root-form implants placed in subantral grafted sites. J Calif Dent Assoc 1993;1:31–35.
34. Van Dyke TE, Sheilesh D. Risk factors for periodontitis. J Int Acad Periodontol 2005;1:3–7.
35. Johnson GK, Guthmiller JM. The impact of cigarette smoking on periodontal disease and treatment. Periodontol 2000 2007:178–194.
36. Sánchez-Pérez A, Moya-Villaescusa MJ, Caffesse RG. Tobacco as a risk factor for survival of dental implants. J Periodontol 2007;2: 351–319.
37. Costa FO, Takenaka-Martinez S, Cota LO, et al. Peri-implant disease in subjects with and without preventive maintenance: A 5-year follow-up. J Clin Periodontol 2012;2:173–181.
38. Pesce P, Canullo L, Grusovin MG, et al. Systematic review of some prosthetic risk factors for periimplantitis. J Prosthet Dent 2015;114:346–350.
39. Jepsen S, Berglundh T, Genco R, et al. Primary prevention of peri-implantitis: Managing peri-implant mucositis. J Clin Periodontol 2015:S152–S157.
40. Humphrey S. Implant maintenance. Dent Clin North Am 2006;3: 463–478.
41. Todescan S, Lavigne S, Kelekis-Cholakis A. Guidance for the maintenance care of dental implants: Clinical review. J Can Dent Assoc 2012:c107.
42. Lang NP, Nyman SR. Supportive maintenance care for patients with implants and advanced restorative therapy. Periodontol 2000 1994:119–126.
43. Wilson TG Jr, Valderrama P, Rodrigues DB. The case for routine maintenance of dental implants. J Periodontol 2014;5:657–660.
44. Wilson TG Jr. A typical maintenance visit for patients with dental implants. Periodontol 2000 1996:29.
45. Dvorak G, Arnhart C, Heuberer S, et al. Peri-implantitis and late implant failures in postmenopausal women: A cross-sectional study. J Clin Periodontol 2011;10:950–955.
46. Dowell S, Oates TW, Robinson M. Implant success in people with type 2 diabetes mellitus with varying glycemic control: A pilot study. J Am Dent Assoc 2007;3:355–361; quiz 97–98.
47. Michaeli E, Weinberg I, Nahlieli O. Dental implants in the diabetic patient: Systemic and rehabilitative considerations. Quintessence Int 2009;8:639–645.
48. Anner R, Grossmann Y, Anner Y, Levin L. Smoking, diabetes mellitus, periodontitis, and supportive periodontal treatment as factors associated with dental implant survival: A long-term retrospective evaluation of patients followed for up to 10 years. Implant Dent 2010;1:57–64.
49. Turkyilmaz I. One-year clinical outcome of dental implants placed in patients with type 2 diabetes mellitus: A case series. Implant Dent 2010;4:323–329.
50. Javed F, Romanos GE. Impact of diabetes mellitus and glycemic control on the osseointegration of dental implants: A systematic literature review. J Periodontol 2009;11:1719–1730.
51. Busenlechner D, Fürhauser R, Haas R, et al. Long-term implant success at the Academy for Oral Implantology: 8-year follow-up and risk factor analysis. J Periodontal Implant Sci 2014;3:102–108.