

Factors Associated With Crestal Bone Loss Following Dental Implant Placement in a Longitudinal Follow-up Study

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The purpose of this study is to estimate the magnitude of crestal bone loss and to identify factors associated with changes in crestal bone height following placement of dental implants. This was a retrospective cohort study, consisting of a sample derived from the population of patients who had at least 1 dental implant placed in a community practice over a 10-year period. A total of 11 predictor variables were grouped into demographic, related health status, anatomic, implant-specific, and operative categories. The primary outcome variable was a change in crestal bone height (mm) over the course of follow-up. The secondary outcome variable was crestal bone loss at 1 year grouped into 2 categories (bone loss >1.5 mm and ≤ 1.5 mm). Univariate and multivariate regression mixed-effects models were developed to identify variables associated with crestal bone level changes over time. *P* values $\leq .05$ were considered statistically significant. The study sample was composed of 85 subjects who received 148 implants. The mean change of the crestal bone was -2.1 ± 1.5 mm (range = -12.5 to 0.5 mm; median = -1.77 mm). In the multivariate model, none of the variables studied were statistically associated with mean crestal bone loss. Among 84 (66.1%) implants with bone loss >1.5 mm within 1 year, no variables were associated with bone loss in the multivariate model. Of the 11 predictor variables evaluated in this study, none were statistically significant with regard to an increased risk for crestal bone loss or for excessive bone loss within the first year after implant placement.

Key Words: crestal bone changes, dental implants, risk factors

INTRODUCTION

The factors associated with a prognosis of dental implants and implant failure have been studied immensely.¹⁻⁵ Crestal bone loss less than 1.5 mm in the first year and subsequent annual bone level changes of 0.2 mm at the implant and bone interface are generally accepted as within the limits of a normal physiologic process.^{6,7} Although this loss of crestal bone height around the implant during the early healing phase has been considered an acceptable physiologic change, continued loss of crestal bone height following osseointegration may result in increased mobility and subsequent failure.⁸

Factors thought to influence the number of changes in crestal bone height after implant placement include delayed vs immediate implant placement, staging, timing of implant loading, requirement of bone graft at the implant site, presence of infection, medical conditions that compromise wound healing, smoking, status of oral hygiene, location of implant placement, and size of the implants.¹⁻⁵ Other mechanical factors such as periosteum elevation during surgery, overheating of the instrument resulting in osteonecrosis, occlusal trauma, cantilever effect, and physiologic bone remodeling from inflammatory process and plaque accumulation have been also suggested.⁹

The purpose of this study was to estimate the magnitude of crestal bone loss at 1 year following dental implant placement and to identify factors associated with increased bone loss. The investigators hypothesized that there was a set of discrete, identifiable factors associated with increased levels of bone loss, and these variables may be manipulated by clinicians to enhance outcomes. The specific aims were (1) to enroll a cohort of subjects who had at least 1 dental implant placed, (2) to measure crestal bone heights before and following implant placement, and (3) to develop and implement a multivariate model to identify variables associated with bone loss.

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FIGURE. Radiographic measurement of crestal bone loss changes.

MATERIALS AND METHODS

Study design/sample

This was a retrospective cohort study. The investigators enrolled a cohort of subjects who underwent dental implant placement (Nobel Replace Select, Nobel Biocare, Mahwah, NJ) between January 1997 and September 2006 in a community oral and maxillofacial surgical practice. Every implant was placed in standard fashion using a full-thickness mucoperiosteal flap. Every patient received a preoperative dose of antibiotics. Patients were included as subjects if they had at least 1 dental implant placed during the study period and had complete follow-up data, including clinical and radiographic assessments. Patients were excluded from the study if their charts were missing or had incomplete data. This retrospective cohort study with review of charts was approved by the institutional review board. Also, this study was conducted in accordance with the ethical principles of the World Medical Association Declaration of Helsinki.

Study variables

Predictor variables. The predictor variables were composed of a set of heterogeneous variables classified as demographic (age and sex), related health status (smoking history and American Society of Anesthesiology Classification [ASA] status), anatomic variables (implant location, ie, maxilla vs mandible and anterior vs posterior), implant-specific (implant diameter and length), and operative factors (loading: placement of a crown portion prosthesis at the time of an implant placement to function; immediate implant: placement after extracting a tooth or preexisting implant; staging: placement of healing abutment exposed through the gingiva vs healing cap buried under the gingiva; dentoalveolar reconstruction procedures [DRPs], eg, sinus lift, ridge augmentation).

Outcome variables. The primary outcome variable was a change in crestal bone height over the course of follow-up. The secondary outcome variable was crestal bone loss at 1 year, and

it was coded as bone loss ≤ 1.5 mm and bone loss > 1.5 mm. Changes in crestal bone height were estimated by measuring radiographs corrected for magnification by calculating a ratio of the actual implant length divided by the measured radiographic implant length (Figure). The comparison was made between the first postoperative radiograph and the latest follow-up radiograph. The corrected crestal bone level = actual implant length/measured implant length \times measured crestal bone height. Measurements were made at the mesial and distal crestal bone levels. The lowest crestal height measurement was used for analyses.

Data management and statistical analysis

A database was created using Excel 2007 (Microsoft Inc, Seattle, Wash) with appropriate checks to identify errors. Descriptive statistics were computed for all study variables. Univariate and multivariate regression mixed-effects models, if indicated, were developed to evaluate possible associations between the predictor variables and crestal bone level changes. For the secondary outcome measure, Cox proportional hazards modeling was used to identify patients at risk for excessive crestal bone loss with bone loss > 1.5 mm within a year after implant placement. A commercially available statistical software package (SAS v.9.3, 2002–2010, SAS, Cary, NC) was used for analyses. When assessing the univariate models, candidate variables with P values $\leq .15$ were considered. These eligible candidate variables were then further considered when evaluating the multivariate model. The statistical level of significance, P values $\leq .05$, were considered statistically significant when multivariate models were assessed.

RESULTS

Over the study period, 85 patients received 184 implants (see Table 1 for a summary of the sample's descriptive statistics). The sample was composed of 43 (50.6%) men with a mean age of 55 ± 12.3 years.

A total of 23 implants (15.5%) were placed in 11 (12.9%) smokers. Most patients were ASA class I (82 patients, 96.5%; 141 implants, 95.3%). In addition, 7 implants (4.7%) were placed in 3 (3.5%) patients with a diagnosis of diabetes, prior chemotherapy or radiation therapy, or liver disease.

A total of 57 implants (38.5%) were placed in the lower jaw, and 49 implants (33.1%) were placed anteriorly in both jaws. A total of 148 implants were evaluated and noted as placed adjacent to either tooth, implant, or both; 30.4% of the implants were placed in between 2 natural teeth.

Implant diameters varied from 3.25–6.0 mm, with associated lengths of 8.0–18.0 mm. The mean diameter and lengths were 4.4 ± 0.7 mm and 12.2 ± 1.6 mm, respectively. A total of 66 implants (44.6%) were coated and 49 implants (33.1%) were immediately loaded; 99 (66.9%) were loaded in delayed fashion. Among those immediately placed, 35 (23.7%) were placed following the extraction of a tooth and 2 (1.4%) were placed following the removal of an implant. The remaining implants (111; 75%) were placed in delayed fashion. Exactly 103 (69.6%) implants were placed using a 2-stage protocol; 45 (31.4%) were

TABLE 1
Descriptive statistics of patient-specific and implant-specific variables

Variable		n (Subjects) or k (Implants), %
Sample size (n = 85 subjects)		
Age	55 ± 12.3 (17–83)	
Sex	Male	43 (50.6)
Smoker	Yes	11 (12.9)
ASA status	ASA I	82 (96.5)
	ASA II	3 (3.5)
Implant-specific variable		
Number of implants inserted (k = 148)		
Anatomic		
Jaw location	Maxilla	91 (61.5)
	Mandible	57 (38.5)
Anteroposterior location	Anterior	49 (33.1)
	Posterior	99 (66.9)
Proximity of implant*	No adjacent teeth	5 (3.4)
	1 adjacent tooth	13 (8.8)
	2 adjacent teeth	45 (30.4)
	1 adjacent implant	24 (16.2)
	2 adjacent implants	19 (12.8)
	1 tooth, 1 implant	42 (28.4)
Implant diamete	Narrow (3.25– 3.5 mm)	23 (15.6)
	Regular (3.75–4.5 mm)	65 (43.9)
	Wide (>5 mm)	60 (40.5)
Implant length	0 = short (8 mm)	3 (2.0)
	1 = average (10–11.5 mm)	63 (42.6)
	2 = long (13–15 mm)	82 (55.4)
Implant coating	Yes	66 (44.6)
Loading (k = 148)	Immediate	49 (33.1)
Immediate implant placement (k = 148)	No	111 (75)
	After tooth removal	35 (23.7)
	After implant removal	2 (1.4)
Staging of abutment placement (k = 148)	2-stage	103 (69.6)
	1-stage	45 (31.4)
Dentoalveolar reconstruction procedure at implant site (k = 148)	Yes	62 (41.9)
Crestal bone loss ≤1.5 mm (k = 127)	≤12 mo	43 (33.9)
Crestal bone loss >1.5 mm (k = 127)	≤12 mo	84 (66.1)
Change in crest bone height, mm	Mean ± SD	Median (range)
Time interval, d (k = 148)	265.9 ± 371.9	151 (15 to 2057)
Mesial bone (k = 148)	−1.71 ± 1.61	−1.54 (−12.5 to 0.53)
Distal bone (k = 148)	−1.78 ± 1.31	−1.64 (−7.5 to 0.53)
Worst bone (k = 148)	−2.14 ± 1.54	−1.77 (−12.5 to 0.53)

*Each implant was evaluated for adjacent structures.

placed in 1 stage with placement of a healing or restorative abutment on the same day.

The DRPs such as an internal or external sinus lift, ridge split, onlay, or inlay graft were performed on 62 (41.9%) implants. Immediate DRPs were performed at the time of implant placement in 43 (69.4%) implant sites. The bone graft materials used were autogenous (9; 14.5%), allogenic (demineralized bone powder; 40; 64.5%), and alloplastic (7; 11.3%). Six (9.7%) implant sites received a combination of bone graft types, and 28 (18.9%) bone graft sites were reinforced with a resorbable membrane.

Implant restorations included single-unit crown (69; 48.9%), fixed bridge (52; 36.9%), fixed denture/hybrid (10; 7.1%), and overdenture or removable prosthesis (10; 7.1%). One implant was incorporated in a prosthesis with 2 natural teeth. The total number of implants used in the prosthesis varied from 1 to 6

implants; the number of teeth not supported by the implants in the prosthesis ranged from 0 to 12.

The median duration for follow-up was 0.7 years (range, 0.04–5.64 years). The mean change of the crestal bone was -2.1 ± 1.5 mm (range = -12.5 – 0.5 mm with median -1.77 ; Table 1). In the univariate model, 2 variables, ASA and immediate implant placement, were near statistically associated with crestal bone loss (Table 2). None of the variables were statistically significant with regard to bone loss in the multiple regression models (Table 3).

A total of 84 implants (66.1 %) had >1.5 mm of bone loss within 1 year (Table 1). In the univariate model (Table 4), 2 variables, smoker and anterior/posterior location, were near statistically significant with regard to bone loss categorized as a binary variable. However, none of the variables were statistically significant in multivariate Cox hazards analysis (Table 5).

TABLE 2

Univariate mixed regression analysis of variable associated with worst crestal bone changes

Predictor Variable	P Value
Age	.3
Sex	.8
ASA	.1
Smoker	.9
Location: maxilla/mandible	1.0
Location: anterior/posterior	.5
Immediate implant*	.1
Loading†	1.0
Implant diameter	.5
Implant length	.7
Stage‡	1.0
DRP§	.3

*Immediate implant is the placement of implant in the socket at the time of tooth extraction or removal of implant.

†Loading is the placement of restoration at the time of implant placement.

‡Stage is the placement of implant submucosally with healing cap (2-stage) vs placing the healing abutment (1-stage) at the time of implant placement.

§DRP is dentoalveolar reconstruction procedure: augmentation of implant sites with bone grafting.

Discussion

The purpose of this study was to estimate the magnitude of crestal bone loss and to identify factors associated with changes in crestal bone height following placement of dental implants. The investigators hypothesized that there was a set of 1 or more variables associated with increased levels of bone loss that may be manipulated by the clinician to enhance outcomes or may help to identify patients at risk for excessive crestal bone loss. In brief, changes in crestal bone height during the study interval (from 15 to 2057 days) had a mean loss of 2.1 ± 1.5 mm and 66.1% of implants had >1.5 mm of bone loss at 1 year. The results of this study failed to confirm the proposed hypothesis. The investigators did not identify any variables associated with crestal bone loss that may be modified by the clinician to preserve crestal bone.

The change in crestal bone height after the implant placement was quantified using radiographic measurements, which were corrected by the magnified factors. The margin of error and limitation still exist in evaluating linear bone changes in nonidentical radiographs using reference dimensions of the implants.¹⁰ However, the precision and the validity of the measurement on noninvasive radiographic images were

TABLE 3

Multivariate mixed regression analysis of variable associated with worst crestal bone changes

Predictor Variable	Parameter Estimate	95% Confidence Interval	P Value
Age	0.01	(-0.01 to 0.03)	.4
Sex	0.02	(-0.5 to 0.6)	.9
ASA	-1.2	(-2.6 to 0.2)	.1
Immediate implant	-0.3	(-0.9 to 0.3)	.3

TABLE 4

Univariate Cox hazards analysis of variable associated with crest bone loss >1.5 mm within 1 year after the implant placement

Predictor Variable	Hazard Ratio (95% Confidence Interval)	P Value
Age	1.0 (0.99-1.02)	.6
Sex	1.1 (0.6-1.9)	.7
ASA	1.2 (0.7-1.9)	.5
Smoker	1.6 (0.9-2.7)	.1
Location: maxilla/mandible	0.9 (0.5-1.6)	.7
Location: anterior/posterior	0.6 (0.4-1.0)	.1
Immediate implant*	0.9 (0.5-1.6)	.7
Loading†	0.9 (0.4-1.9)	.8
Implant diameter	0.9 (0.7-1.3)	.7
Implant length	1.1 (0.9-1.2)	.5
Stage‡	1.1 (0.5-2.7)	.8
DRP§	1.4 (0.8-2.3)	.3

*Immediate implant is the placement of implant in the socket at the time of tooth extraction or removal of implant.

†Loading is the placement of restoration at the time of implant placement.

‡Stage is the placement of implant submucosally with healing cap (2-stage) vs placing the healing abutment (1-stage) at the time of implant placement.

§DRP is dentoalveolar reconstruction procedure: augmentation of implant sites with bone grafting.

adequate when compared with the histometric analysis.¹¹ The predictor variables were individually discussed and compared with previous studies.

Surface design

The aim to discover the modifiable predictor factors to improve dental implant success rates have been extensively studied in the literature. The types of implant design and surface are known to influence the crestal bone changes. Valderrama et al⁸ demonstrated the histological evaluation of crestal bone gain with the use of chemically modified, sandblasted, acid-etched (SLA) surfaced implants without a machined collar on animal models after 3 and 12 months under loading conditions in the canine mandible. Also, high-implant success rates on irradiated oral squamous cell carcinoma patients was shown with chemically modified implants (n = 28) and conventional SLA titanium surface implants (n = 27), 100% and 96%, respectively.¹² The implant with a longer machined collar length showed no significant difference in bone loss, and the shorter collar was

TABLE 5

Multivariate Cox hazards analysis of variable associated with crest bone loss >1.5 mm within 1 year after the implant placement

Predictor Variable	Hazard Ratio (95% Confidence Interval)	P Value
Age	1.0 (0.99-1.03)	.4
Sex	1.1 (0.6-1.8)	.8
Smoker	1.5 (0.9-2.6)	.1
Location: anterior/posterior	0.6 (0.3-1.0)	.1

recommended for the area with esthetic concerns.¹³ The randomized controlled study from Shin et al¹⁴ demonstrated significantly decreased crestal bone loss ($P < .05$) with rough surfaced microthreads at the implant neck compared with the machine-surfaced group.

Ideally, subcrestally placed implants would show optimal osseointegration and have a greater success rate; however, subcrestally placed implants, especially smooth-collared implants, showed greater crestal bone changes.⁶ In contrast, the radiographic study by Hermann et al¹⁵ showed rapid bone remodeling during the early healing phase after implant placement for nonsubmerged implants and after abutment connection for submerged implants.

Loading

Implant placement is followed by prosthesis placement as a final restorative step either in immediate or delayed fashion. The restorations consist of single-unit or multi-unit crowns, or dentures. The benefit of immediate loading at the time of implant placement is still controversial. The crestal bone changes were not significantly different with regard to implant stability on immediate loading of 2 implants supporting a magnet attachment retained overdenture.⁹ However, Susarla et al¹⁶ stated that the immediately loaded implant is 2.7 times more likely to fail at 1 year compared with delay-loaded implants. In contrast, the crestal bone level changes with immediately loaded implants were within the recommended range for 92.5% of the evaluated implants.⁷ The preliminary study by Brochu et al¹⁷ indicated that early loading did not show an influence on crest bone height or stability during a 4-month follow-up period. The histologic evaluation of the animal model also demonstrated that the loading is not a relevant factor in peri-implant bone resorption for 1-year function.¹⁸ The progressive loading concept on a conventional staged implant placement was evaluated using digital imaging analysis and digital subtraction to determine the effectiveness on preserving crestal bone height and peri-implant bone density. Imaging on the conventional staged implants resulted in less bone loss and increased peri-implant density in the progressive loading group.¹⁹ Also, the length of cantilever extension on implant-supporting cantilevered bar-retained dentures showed no influence on crestal bone changes.²⁰

Immediate implant

Immediate implant placement, after extraction, significantly reduces overall treatment time for patients; therefore, it is preferred by many surgeons when indicated. However, immediate implant placement, especially with xenograft bone graft, showed an increase in bone loss on buccal aspects with low osseointegration.²¹ Block et al²² compared hard- and soft-tissue response to immediate and delayed placement of an implant in the maxillary anterior region with immediate provisionalization. This study concluded that the hard-tissue change was similar in the 2 groups; however, 1 mm more facial gingival margin was preserved on immediate implant with provisionalization.²² Immediate implant placement with provisionalization seems to preserve soft tissue

with possible negative effects on bone loss.^{21,22} However, some argue that the crestal bone loss after immediate implant placement with or without bone grafting is clinically acceptable.^{23–25} Therefore, evaluation for the appropriateness of immediate implant placement should be individually assessed to provide the best outcome.

Staging

The 2-stage surgical approach for dental implant placement appeared to minimize the amount of crestal bone loss. Toljanic et al²⁶ demonstrated that early soft-tissue exposure of the implant between stage I and stage II surgery is 3.9 times more likely to result in bone loss. These differences may be the result of plaque accumulation and inflammation at the early perforation and partial exposure of the implant.²⁷ The rate of bone loss after implant placement is greater during the initial healing phase, after which the rate slows down.^{28–30} A direct relationship exists between spontaneously early, cover-screw perforation and early crestal bone loss.³¹ Linkevicius et al³² compared the thickness of the soft tissue on the crestal bone around the dental implant and stated that if the tissue thickness is 2.0 mm or less, crestal bone loss up to 1.45 mm may occur. These studies suggest that thicker gingival tissue on crestal bone has lesser bone changes and stress the importance of good closure of the gingival flap to minimize the increase in bone loss due to early implant exposure to the oral cavity.

In contrast, the 10-year prospective study by Kim et al²⁹ evaluated crestal bone loss on 1-stage dental implants and showed clinically acceptable bone loss. Also, the 8-year follow-up on the 1-stage surgical approach for screw-retained full-arch prostheses in maxilla showed minimal crestal bone loss of 0.3 ± 0.72 mm.³³ Our study did not show statistical significance of staging implants correlating to crestal bone change; however, it would be prudent to avoid 1-stage implant placement on an area with inadequate or marginal alveolar bone where even minimal bone loss can be detrimental to implant survival.

Dentoalveolar reconstructive procedures

Bone grafting is used during the dental extraction and socket preservation method for future implant placement. Bone grafting is also readily used concurrently with implant placement with barrier membranes to enhance the deficient implant recipient site. The need for bone grafting at the implant site suggests a lack of adequate alveolar bone around the implant site. Therefore, the dentoalveolar reconstructive procedure indicates a less than optimal implant environment. The types of reconstructive procedures available include a broad spectrum from simple bone grafting, to onlay, sinus lifting, or ridge splitting. Bone-grafting materials are autologous, allograft, xenograft, or synthetic. There are pros and cons of each with different chemical and physiological properties such as osteogenesis, osteoinduction, or osteoconduction capabilities. Not all bone grafting is successful and may result in a high percentage of clinically significant resorption. This is likely due to predisposed less-optimal bone for the implant in combination with resorption of the grafting materials. However, the retrospective cohort study by Woo et

al³⁴ suggested that the use of DRP was not an independent factor for implant failure.

Studies^{21,35} show significant buccal bone loss after a xenografting procedure and fail to demonstrate the positive effects of xenograft on osseous wound defect between the bone crest and the coronal aspect of the implants. Koutouzis and Lundgren²⁴ demonstrated the comparable crestal bone changes on 12-month follow-up between implants placed in an allograft reconstructed socket v. native bone, with a mean marginal bone loss of 0.15 mm for both groups. Local bone graft procedures can provide an adequate amount of bone for an implant placement; however, the resorption pattern, especially in the anterior, is unpredictable with individual variation.³⁶ The maxillary sinus augmentation precedes the implant placement on loss of vertical height in the posterior maxilla to accommodate the bulk of the bone for the implant. Unlike the risk factor of tobacco use, immediate implant, and implant staging, the maxillary sinus augmentation procedure showed no association with increased risk factor for implant failure.^{1,3-5,34} Other risk factors for implant failure included implant length and proximity of an adjacent implant.³ The amount of bone remodeling and resorption after the bone graft procedure is unpredictable; however, early detection and treatment of early progressive bone loss around the dental implants showed an improved implant failure rate.³⁷

The limitation of the study includes the use of data from a single surgical center with limited long-term follow-up on many patients. In an attempt to minimize the radiographic measurement error and to ensure reliability, the same person performed the measurement. To detect an association between the dependent variable and the independent variable on univariate analysis, we would need a total of 800 implants for a detection power of 80% at a 2-sided 5% significance level if the true change in the dependent variable is 0.1-mm bone-level change per 1-unit change in the independent variable.

Examination of these variables in an appropriately powered prospective study might find that some of these variables have a negative impact on the long-term stability of crestal bone. Further study of a large sample size would determine the effects of predictor variables, which can be modified by patients and surgeons to improve the amount of crestal bone change and overall implant survival as well as to identify patients at risk for increased bone loss.

CONCLUSION

In this study, the mean bone loss following implant placement was 2.1 mm, and 66.1% of the implants had >1.5 mm of bone loss in the first year. None of the variables included in analyses were statistically significant with regard to an increased risk for crestal bone loss or excessive bone loss within the first year after implant placement.

ABBREVIATIONS

ASA: American Society of Anesthesiology Classification
DRP: dentoalveolar reconstructive procedure
SLA: sandblasted, acid etched

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