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Implant Site Development Requirements in an Advanced Dental Education Program: A Series of 290 Cases

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ABSTRACT

Purpose: Our purpose was to assess the types, timing, and impact of site development procedures provided before, during, and after implant placement in an advanced dental education program.

Methods: We evaluated all implant cases completed by two residents in each of three consecutive periodontics residency classes. Dependent variables included implant failure, complication occurrence, presence of radiographic bone loss (RBL), and need for tissue augmentation. We analyzed these outcomes against a panel of explanatory covariates.

Results: Our study sample involved 290 implants in 160 patients. Three factors exhibited statistically significant associations with need for tissue augmentation: alveolar ridge preservation (ARP) (OR 0.28; 95% CI 0.13, 0.57), immediate implant placement (IIP) (OR 0.21; 95% CI 0.10, 0.47), and submerged implant (OR 8.3; 95% CI 4.5, 15.3). Four factors predicted treatment complications: ARP (OR 6.1; 95% CI 1.3, 29.1), IIP (OR 6.1; 95% CI 1.06, 35.3), submerged implant (OR 5.3; 95% CI 1.1, 24.9), and mandibular arch (OR 31.3; 95% CI 1.9, 500). Anterior sites (OR 2.7; 95% CI 1.3, 5.8) were more likely to receive IIP.

Conclusions: In the evaluated sample, implant placement in a favorable volume of native bone was rare. A strikingly high proportion of sites received hard tissue augmentation during the treatment phase. Use of ARP or IIP at tooth extraction reduced subsequent tissue augmentation requirements. Education and training in ARP and other site development procedures may enhance the clinical practice and treatment outcomes of implant surgeons.

Keywords: Dental implants; alveolar ridge augmentation; allografts; tissue transplantation; tooth extraction; treatment outcome

INTRODUCTION

Because implant therapy is a well-documented treatment with substantial impact on quality of life, patients are fortunate that many clinicians—in various disciplines—offer this service. In 2009, the First European Consensus Workshop on Implant Dentistry University Education outlined guidelines for competence-based education in implant dentistry and defined key elements within postgraduate implant curricula.[1,2] Intuitively, a clinician's thought processes and actions when providing implant treatment have direct bearing on the quality of the outcome, and these factors strongly depend on education and training.[3] Thus, regardless of specialty, analyzing and improving the training that implant surgeons receive are worthy endeavors.

Clearly, implant surgeons require in-depth understanding of peri-implant hard and soft tissues. Over the past fifteen years, it has become increasingly apparent that health and stability at dental implant sites depend, in part, on the volume and quality of bone and keratinized mucosa present.[4-7] Hard and soft tissue deficiencies at dental implant sites can result in mucosal recession, exposure of implant components, poor esthetics, diminished cleansability, and predisposition toward biologic complications, primarily peri-implant mucositis and peri-implantitis.[4-7] Although hard and soft tissue requirements at dental implant sites have become progressively clarified, the frequency at which implant sites actually meet these requirements remains poorly defined.

Hard tissue requirements at dental implant sites

According to the 2017 World Workshop on Classification of Periodontal and Peri-implant Diseases and Conditions, a "hard tissue deficiency prior to implant placement" exists when alveolar ridge dimensions do not accommodate a standard implant fully embedded in the local host bone.[5] Beyond merely embedding an implant in bone, multiple authors suggest that a minimum peri-implant bone thickness is necessary.[8-12] In a critical-sized, supra-alveolar, peri-implant defect model in dogs, crestal resorption after implant installation depended on the width of the alveolar bone.[8] The extent of the resorption was more pronounced when the bone thickness was less than two millimeters.[8] Spray and colleagues found, in a multicenter study investigating peri-implant bone loss between implant surgery and stage two uncovering, a negative correlation between baseline peri-implant bone thickness and bone resorption over the observation period.[9] Patients with peri-implant bone thickness < 1.4 mm exhibited the greatest reduction in horizontal alveolar ridge dimension.[9] Conversely, patients with baseline peri-implant bone thickness exceeding 1.8 mm experienced significantly less bone loss, and in some cases, gained bone thickness.[9] Assessing cone-beam computed tomography (CBCT) volumes acquired after implant restoration, Miyamoto and Obama found that facial bone thickness of at least 1.2 mm was associated with reduced risk of mucosal recession at implant sites in the esthetic zone (immediate or delayed placement).[10] In clinical practice, providers commonly round the threshold bone thickness for reliable tissue stability to two millimeters, some experts cautioning that even greater thickness is preferable.[11] Despite broad consensus regarding the need for peri-implant bone thickness ≥ 2 mm, only two reports have estimated the frequency with which implant sites actually meet this threshold. Bornstein and coworkers conducted a retrospective analysis of patient-, site-, and procedure-related characteristics of implant patients referred to a specialty dental practice in Bern, Switzerland, over a three-year period.[13] Over half of the patients needed a bone augmentation procedure, predominantly alveolar ridge augmentation, at some point during the course of therapy.[13] Wilson and Johnson assessed mesiodistal space and faciolingual alveolar width (FAW) available for implant placement at anterior tooth positions on cone-beam computed tomography volumes from 205 patients.[14] Over half of maxillary incisor sites and 78% to 95% of mandibular incisor sites exhibited FAW < 4 mm beyond a standardized implant diameter.[14] Thus, at these sites, peri-implant bone thickness ≥ 2 mm could not be achieved without augmentation.

Soft tissue requirements at dental implant sites

Both the apicocoronal dimension of the attached peri-implant mucosa and the peri-implant mucosal thickness appear relevant factors in the maintenance of health and stability at dental implant sites. Observational studies and systematic reviews support increased plaque accumulation and bleeding at implant sites with keratinized mucosal width (KMW) < 2 mm.[6,15-17] Investigators have also associated KMW < 2 mm with mucosal recession and brushing discomfort.[18,19] Thin peri-implant mucosa (< 2 mm) has been associated with increased marginal bone loss; however, augmentation of thin native mucosa may prevent resorption of peri-implant bone.[6,20-22] Additionally, thin mucosa is a biologic factor negatively influencing the initial physiologic remodeling of bone that occurs following implant surgery.[6,23] Despite consensus that peri-implant mucosal deficiency is unfavorable, no studies identify the frequency with which implant sites lack recommended keratinized mucosal dimensions or quantify the proportion of sites which would benefit from augmentation. The purpose of this study was to assess the types, timing, and impact of hard and soft tissue augmentation procedures provided before, during, and after implant placement in an advanced dental education program in periodontics.

MATERIALS AND METHODS

The Dwight David Eisenhower Army Medical Center Human Protections Administrator reviewed this protocol (#20-11091/930971) and classified our study as "exempt research." We collected data in such a manner that the identity of the human subjects was not readily discernible directly or through identifiers linked with subjects. Our analysis involved all cases completed by six residents—two residents in each Army periodontics residency class graduating in 2018, 2019, and 2020. A single investigator accessed existing patient records, including clinical photographs, to determine the hard and soft tissue augmentation procedures provided at the evaluated implant sites.

The primary outcomes of interest were implant failure, occurrence of at least one treatment complication, presence of interproximal radiographic bone loss (RBL) beyond the first implant thread at any postoperative assessment, and need for hard or soft tissue augmentation. Preservation procedures—alveolar ridge preservation (ARP) and peri-implant gap defect grafting at immediate implant sites—were not considered augmentation for the purpose of this analysis. We compared outcomes against a panel of patient-, site-, and procedure-related covariates. Specifically, independent variables included age, sex, arch (maxillary or mandibular), region (anterior or posterior), current smoking status, prosthesis type (fixed or removable), timing of implant placement (immediate versus delayed), and whether or not the following procedures were performed at the site: ARP, guided bone regeneration (GBR), sinus elevation prior to implant surgery, and sinus elevation concomitantly with implant surgery. Additionally, we aimed to identify associations between patient/site-related covariates and two procedure-related variables—ARP and immediate implant placement (IIP).

Statistical analyses

We calculated descriptive and inferential statistics for all variables using IBM SPSS Statistics for Windows v.27 and assessed statistical significance at an alpha level of 0.05. We performed binomial logistic regression analyses to ascertain the effects of patient-, site-, and procedure-related explanatory variables on each outcome of interest. For each regression model, we used omnibus tests to assess model fit. Linearity of the continuous variable (age) with respect to the logit of the dependent variables was assessed via the Box-Tidwell procedure.

RESULTS

We analyzed a total of 290 implants in 160 patients. Characteristics of the study sample are presented in Table 1. Of the 290 implant sites, 225 (78%) received at least one hard tissue preservation or augmentation procedure at some point during treatment, and 64 (22%) sites received autogenous or allogeneic soft tissue grafts. The study sample included 54 (19%) immediate implants, 76 (26%) implants at ARP sites, 136 (47%) implants at GBR sites, and 48 (17%) implants at sinus augmentation sites. Of the 136 implants at sites receiving GBR, 21 (15%) received GBR on two separate occasions—prior to implant placement, at implant placement, at implant uncovering, or after implant uncovering. Of the 48 sites receiving sinus elevation surgery (SES), 20 (42%) received lateral window SES and 28 (58%) received transalveolar SES. Thirty-one (65%) SESs were staged, whereas 17 (35%) occurred simultaneously with implant placement. Out of the 290 implants placed, 202 (70%) were single implants and 88 (30%) were inserted at sites receiving multiple adjacent fixtures. Twelve implants (4%) failed, resulting in an overall implant survival of 96%. At least one complication—osseointegration failure (early implant failure), infection, excessive bleeding, wound dehiscence, or Schneiderian membrane perforation—occurred at 16 sites (5%), and 5 sites (2%) experienced two complications during the course of treatment.

We performed a binomial logistic regression to ascertain the effects of patient-, site-, and surgery-related factors on the need for tissue augmentation. The logistic regression model was statistically significant, $\chi^2(11) = 85.838$, $p < 0.001$, explaining 35.4% (Nagelkerke R^2) of the variance in the need for augmentation. Three significant predictor variables were found (Table 2). Sites receiving ARP and IIP exhibited 3.62- and 4.69-fold lower odds of subsequent tissue augmentation, respectively. Conversely, submerged implants were 8.29 times more likely to require augmentation (Figure 1).

We performed a binomial logistic regression to ascertain the effects of patient-, site-, and surgery-related factors on complication occurrence. The logistic regression model was statistically significant, $\chi^2(15) = 36.386$, $p = 0.002$, explaining 33.9% (Nagelkerke R^2) of the variance in the complication occurrence. Four statistically significant predictor variables were found (Table 3). Sites receiving ARP, IIP, and implant submersion exhibited 6.06-, 6.12-, and 5.29-fold higher odds of experiencing a complication, respectively. Implants placed in the mandibular arch exhibited 31.25 times higher odds of experiencing a complication (Figures 1 and 2).

We performed a binomial logistic regression to ascertain the effects of patient- and site-related factors on the likelihood of immediate implant placement. The logistic regression model was statistically significant, $\chi^2(6) = 19.556$, $p = 0.003$, explaining 10.6% (Nagelkerke R^2) of the variance in IIP. Two predictor variables were found to be statistically significant (Table 4). Anterior sites and sites receiving a single implant had 2.69- and 3.30-fold higher odds of IIP, respectively. Binomial logistic regression models analyzed for RBL, implant failure, and ARP were not statistically significant ($p = 0.099$, $p = 0.088$, $p = 0.723$, respectively).

DISCUSSION

Results from the present study confirm prior observations[13,14] that a strikingly high proportion of dental implant sites require hard tissue augmentation at some point during treatment. In perspective, well over half of sites in the evaluated sample received a hard tissue augmentaton procedure (GBR, ridge expansion, or sinus elevation). Including ARP and grafted peri-implant gap defects at IIP sites, 78% of evaluated implant sites received some form of hard tissue grafting during the treatment phase. By comparison, a substantially smaller proportion of implant sites (22%) received mucosal augmentation.

Whether inflammatory peri-implant bone loss initiates and progresses more readily in augmented versus pristine bone is a topic of interest in dental implantology.[24-27] In an experimental peri-implantitis defect model in dogs, Carcuac and colleagues observed significantly greater spontaneous progression at augmented sites.[25] In a cross-sectional analysis of 1507 implants in 534 patients, Canullo and collagues found that bone regeneration procedures were associated with higher peri-implantitis prevalence.[26] Contrary to these reports, we did not detect a statistically significant association between GBR and RBL in the evaluated sample. Controlled clinical research is necessary to establish whether or not augmented sites are less resistant to inflammatory peri-implant bone loss.

In our sample, sites receiving ARP or IIP were significantly less likely to require subsequent augmentation with hard or soft tissue. It is well-established that ARP limits the reduction in alveolar ridge volume typically accompanying tooth extraction. In a meta-analysis of ARP outcomes, Bassir and colleagues found a 1.86-mm clinical difference in horizontal alveolar ridge dimension at ARP versus control sites.[28] Another group of investigators reported a similar magnitude of effect, 1.89 mm, in a separate meta-analysis.[29] While a treatment effect < 2 mm seems small, this thickness may represent the difference between stable and unstable peri-implant bone at a considerable number of sites.[8-12]

The observed effect of IIP on the need for tissue augmentation may be attributable to the predominant IIP method applied. At every anterior IIP site in the study sample, the surgeon used the technique described by Chu and colleagues.[30] This protocol involves application of bone biomaterial particles in the soft tissue zone, between the facial mucosa and the provisional crown, in addition to grafting the peri-implant gap defect.[30] Alternatively, other groups of investigators recommend mucosal augmentation using subepithelial connective tissue grafts (SCTGs) at IIP.[31,32] Interestingly, either technique—the Chu method or SCTG augmentation—appears to increase peri-implant mucosal thickness by ≈ 1 mm.[30,32]

Submerged implant sites—those not receiving a transmucosal healing abutment or provisional restoration at implant placement—were more likely to receive subsequent tissue augmentation. Implant uncovering (stage two surgery) is an opportunity to improve keratinized mucosa dimensions or augment the facial peri-implant bone. At sites exhibiting modest deficiencies, we often submerge an implant intending to perform a SCTG or small GBR procedure at implant uncovering. Thus, the observed association is not surprising.

Prior authors have reported comparable survival rates for implants placed in native bone and at sites receiving SES (transalveolar or lateral approach).[33-37] Mulitple reports suggest no difference in implant survival when SES occurs prior to or concomitantly with implant placement.[33-37] Consistent with these findings, we did not identify a statistically significant association between concomitant SES and implant failure.

Given the need for peri-implant tissue augmentation observed in the study sample, and comparable treatment needs reported previously,[13,14] proficiency in implant site development procedures appears helpful, if not essential, for clinicians performing implant surgery. Currently, implant curricula at predoctoral and postdoctoral levels lack standardization and uniformity.[1-3,38,39] Our profession has not yet defined skills and competencies required of implant surgeons nor agreed upon uniform standards, quality assessments, and accreditation requirements across educational pathways.[1-3,38,39] Nevertheless, implant surgeons may place more implants and enhance treatment outcomes through training and experience in site development procedures.

CONCLUSIONS

The majority of dental implant sites evaluated in this study received hard tissue augmentation, soft tissue augmentation, or both. In this sample, implant placement in a favorable volume of native bone was rare. Sites receiving ARP or IIP exhibited reduced likelihood of subsequent tissue augmentation, whereas submerged implants were more likely to require hard or soft tissue grafting. Sites receiving ARP, IIP, implant submersion, or implant placement in the mandibular arch were more likely to experience a complication. Anterior sites and sites receiving single implants were more likely receive immediate placement. Given the apparent need for implant site development procedures within the population, educators designing and implementing implant curricula should allocate sufficient time and resources to this important topic.

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DISCLOSURE

The authors report no financial, economic, or professional interests that may have influenced the design, execution, or presentation of this work. The views expressed in this manuscript are those of the authors and do not necessarily reflect the official policy of the United States Government, the Department of Defense, the Department of the Army, the United States Army Medical Department, or Uniformed Services University of the Health Sciences.

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FIGURES

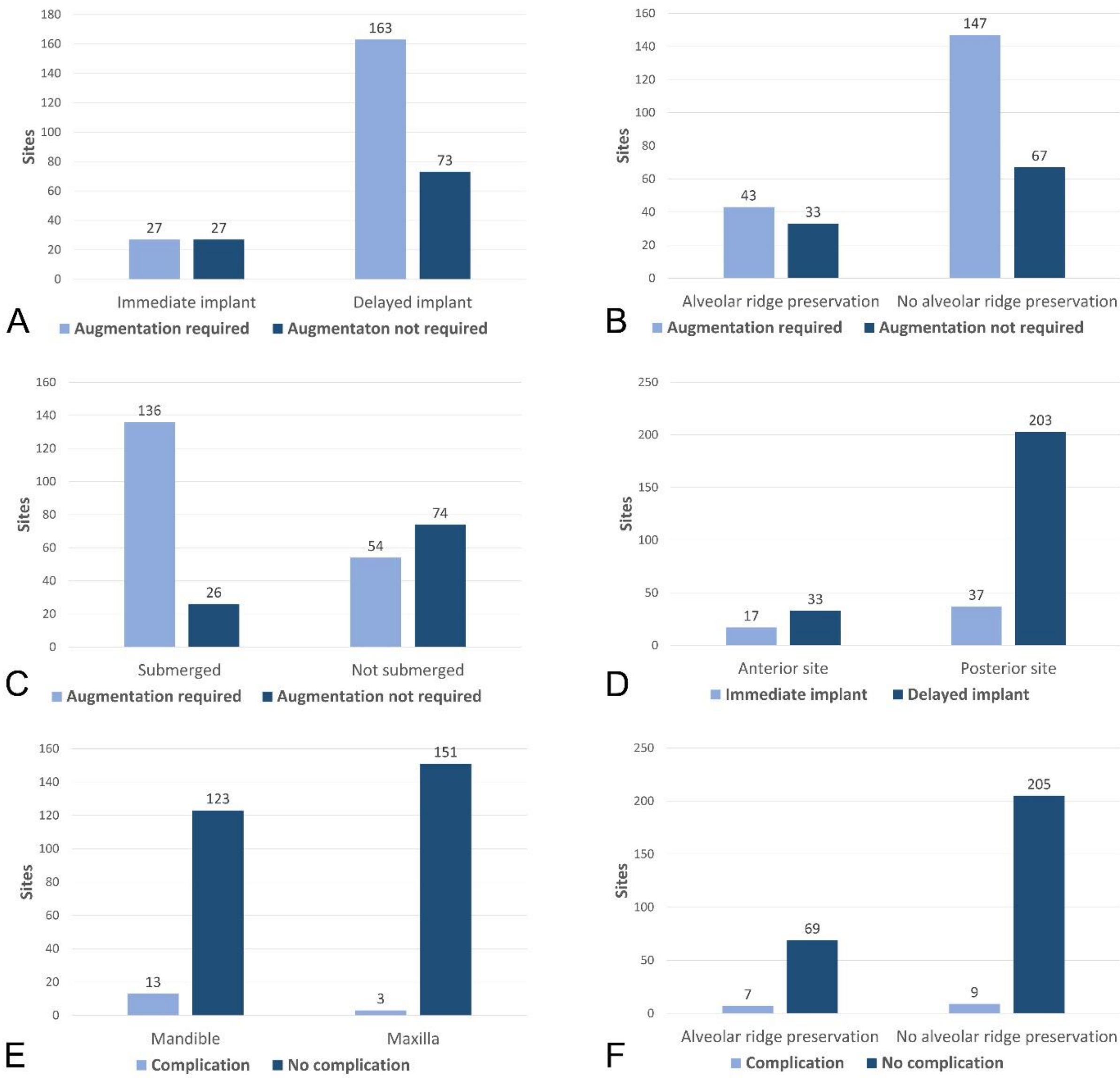

Figure 1. A. Timing of implant placement and requirement for hard or soft tissue augmentation. B. Alveolar ridge preservation and requirement for hard or soft tissue augmentation. C. Implant submergence and requirement for hard or soft tissue augmentation. D. Region and timing of implant placement. E. Alveolar ridge preservation and complication occurrence. F. Dental arch and complication occurrence.

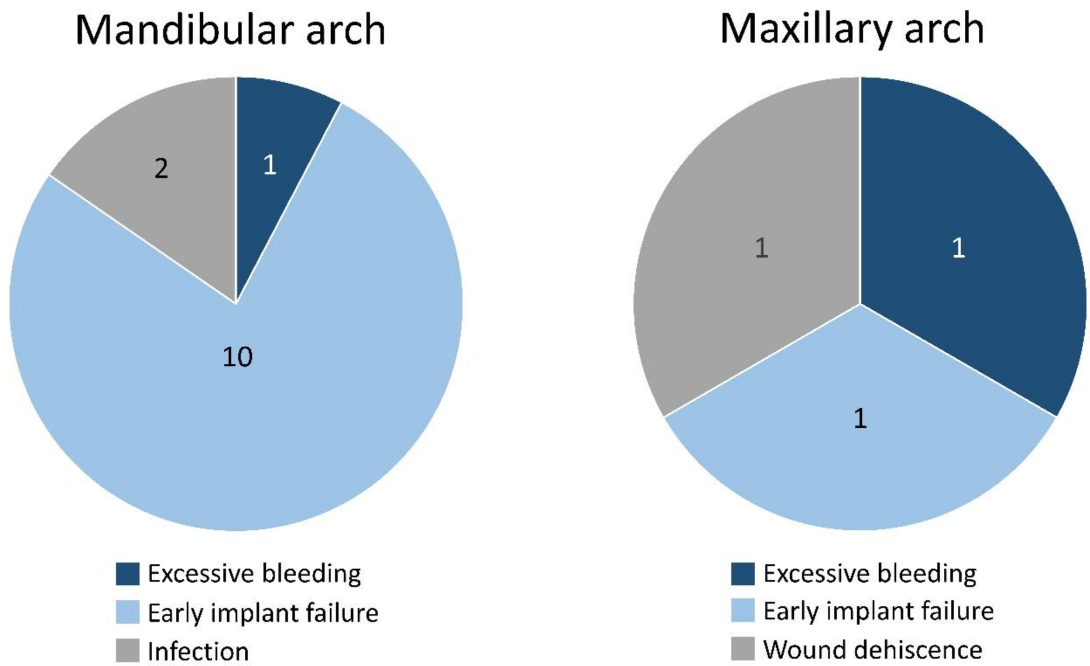

Figure 2. A. Complications occurring in the mandibular arch. B. Complications occurring in the maxillary arch.

TABLES

Table 1. Characteristics of study sample

	Patient level (n = 160)	
Age (years, mean ± SD)	38.8 ± 11.5 (range 20 to 77)	
Sex	44 (28%) Female	116 (73%) Male
Smoking status	26 (16%) Current smoker	134 (84%) Nonsmoker
	Site level (n = 290)	
Patient-related factors		
Age (years, mean ± SD)	40.1 ± 11.8 (range 20 to 77)	
Sex	81 (28%) Female	209 (72%) Male
Smoking status	58 (20%) Current smoker	232 (80%) Nonsmoker
Site-related factors		
Dental arch	154 (53%) Maxilla	136 (47%) Mandible
Region	240 (83%) Posterior	50 (17%) Anterior
Procedure-related factors		
Alveolar ridge preservation	76 (26%) Yes	214 (74%) No
Timing of implant placement	54 (19%) Immediate	236 (81%) Delayed
Prosthesis	25 (9%) Removable	265 (91%) Fixed
Site type	202 (70%) Single implant	88 (30%) Multiple adjacent
Guided bone regeneration at any point	136 (47%) Yes	154 (53%) No
Concomitant sinus elevation and implant placement	31 (11%) Yes	259 (89%) No or not applicable
Staged sinus elevation surgery	17 (6%) Yes	273 (94%) No or not applicable
Autogenous or allogeneic soft tissue graft at any point	64 (22%) Yes	227 (78%) No

Table 2. Logistic Regression Predicting the Need for Augmentation

	B	S.E.	Wald	df	Sig.	Odds Ratio	95% C.I.for Odds Ratio	
							Lower	Upper
Age	-0.017	0.014	1.356	1	0.244	0.984	0.956	1.011
Male gender	-0.149	0.331	0.202	1	0.653	0.862	0.450	1.650
Current smoker	-0.198	0.382	0.268	1	0.605	0.821	0.388	1.735
Maxillary arch	0.620	0.324	3.670	1	0.055	1.859	0.986	3.504
Anterior region	0.607	0.452	1.799	1	0.180	1.834	0.756	4.452
Multiple adjacent implants	0.389	0.363	1.143	1	0.285	1.475	0.723	3.007
Removable prosthesis	0.474	0.656	0.523	1	0.470	1.607	0.444	5.807
ARP	-1.286	0.369	12.154	1	< 0.001	0.276	0.134	0.569
IIP	-1.545	0.403	14.683	1	< 0.001	0.213	0.097	0.470
Submerged implant	2.115	0.312	46.021	1	< 0.001	8.293	4.501	15.280
Complication	0.740	0.711	1.085	1	0.298	2.096	0.521	8.438
Constant	0.502	0.661	0.577	1	0.447	1.652		

ARP = alveolar ridge preservation, IIP = immediate implant placement

Table 3. Logistic Regression Predicting Complication Occurrence

	B	S.E.	Wald	df	Sig.	Odds Ratio	95% C.I.for Odds Ratio	
							Lower	Upper
Age	0.041	0.028	2.221	1	0.136	1.042	0.987	1.100
Male gender	0.686	0.867	0.625	1	0.429	1.985	0.363	10.869
Current smoker	-0.204	0.877	0.054	1	0.816	0.816	0.146	4.549
Maxillary arch	-3.428	1.416	5.864	1	0.015	0.032	0.002	0.520
Anterior region	2.205	1.370	2.590	1	0.108	9.067	0.619	132.919
Multiple adjacent implants	-0.718	0.807	0.791	1	0.374	0.488	0.100	2.374
Removable prosthesis	-2.571	1.956	1.727	1	0.189	0.076	0.002	3.538
ARP	1.801	0.801	5.054	1	0.025	6.055	1.260	29.109
IIP	1.811	0.894	4.103	1	0.043	6.118	1.060	35.298
Submerged implant	1.666	0.789	4.459	1	0.035	5.292	1.127	24.852
Staged SES	3.514	1.913	3.374	1	0.066	33.597	0.790	1428.586
Simultaneous SES	-17.769	5698.358	0.000	1	0.998	0.000	0.000	0.000
GBR at any point	-0.091	0.715	0.016	1	0.899	0.913	0.225	3.705
Soft tissue augmentation at any point	0.124	0.766	0.026	1	0.871	1.132	0.252	5.085
RBL at any point	1.698	0.895	3.602	1	0.058	5.462	0.946	31.537
Constant	-6.627	1.792	13.676	1	0.000	0.001		

ARP = alveolar ridge preservation, IIP = immediate implant placement, SES = sinus elevation surgery, GBR = guided bone regeneration, RBL = radiographic bone loss

Table 4. Logistic Regression Predicting Immediate Implant Placement

	B	S.E.	Wald	df	Sig.	Odds Ratio	95% C.I.for Odds Ratio	
							Lower	Upper
Male gender	-0.313	0.343	0.831	1	0.362	0.731	0.373	1.433
Current smoker	-0.599	0.459	1.703	1	0.192	0.549	0.224	1.351
Maxillary arch	0.015	0.336	0.002	1	0.964	1.015	0.526	1.961
Anterior region	0.989	0.388	6.497	1	0.011	2.689	1.257	5.752
Multiple adjacent implants	-1.193	0.482	6.121	1	0.013	0.303	0.118	0.780
Removable prosthesis	1.013	0.645	2.469	1	0.116	2.755	0.778	9.749
Constant	-1.185	0.345	11.792	1	0.001	0.306		